

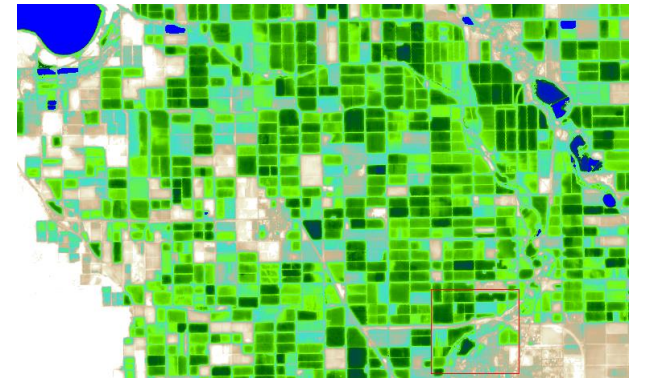
Impacts of 30 meter georegistration on VIIRS spatial fidelity: improvements for water consumption mapping

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DR. AYSE KILIC, UNIV. NEBRASKA-LINCOLN, MEMBER LST





Using VIIRS “SV I-bands” ~ 375 m

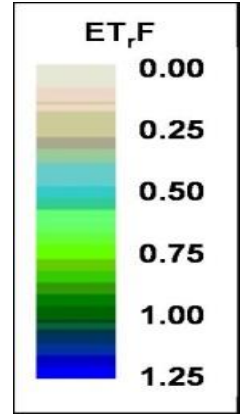
I1 – 0.60 - 0.68 - red

I2 – 0.85 - 0.88 - NIR

I3 – 1.58 - 1.64 - SWIR

I4 – 3.55 - 3.93 – SWIR

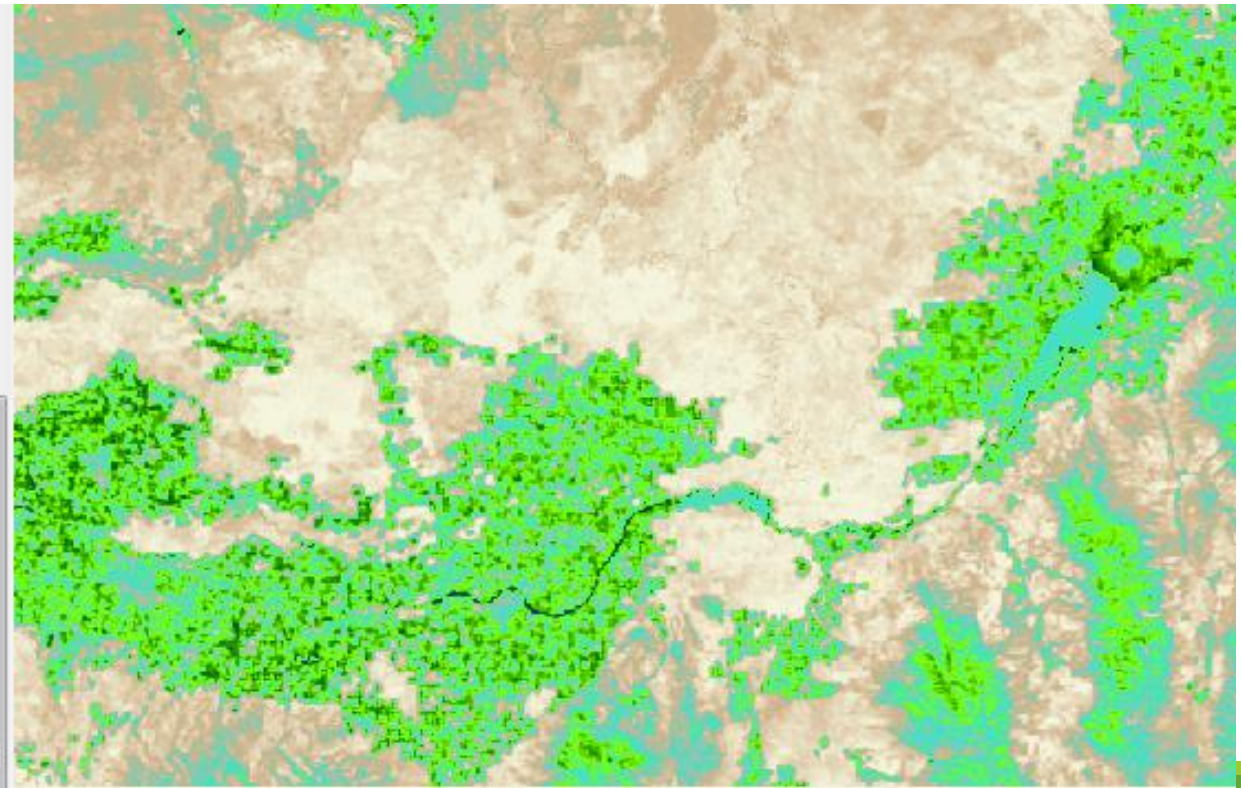
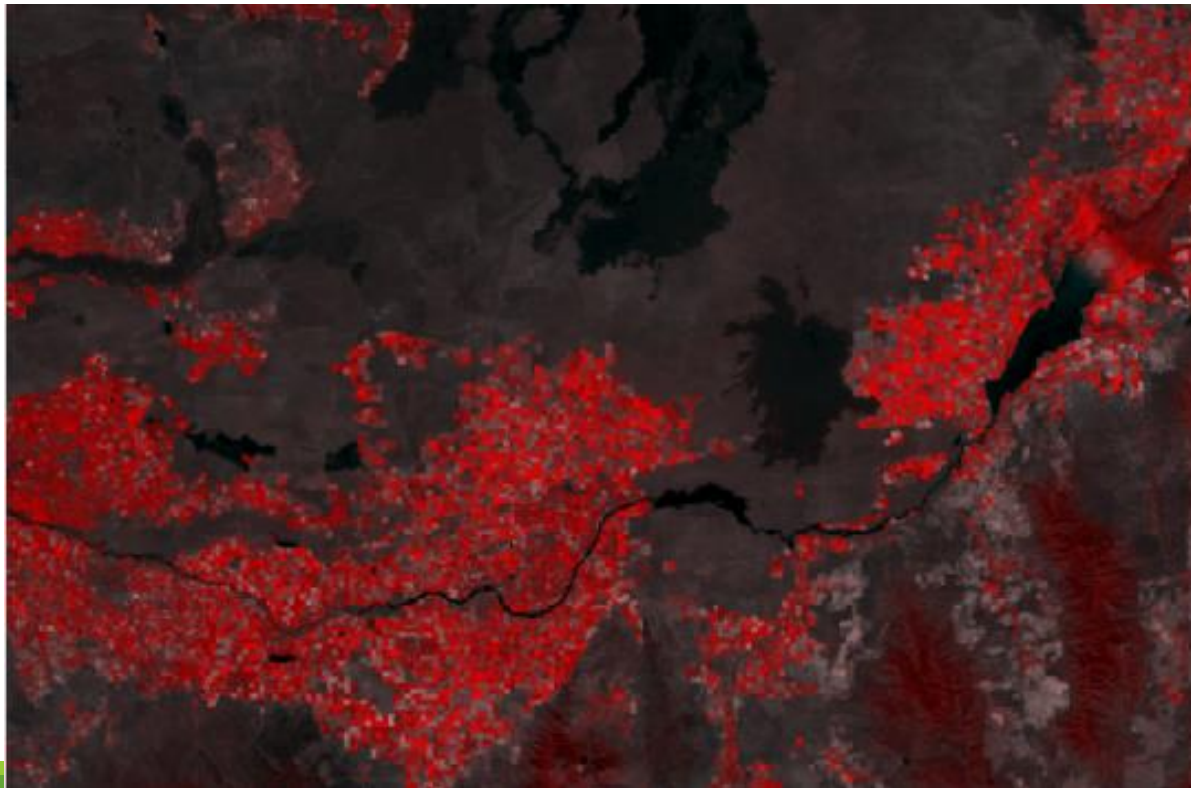
I5 – 10.5 - 12.4 – Longwave IR



VIIRS data are occasionally used to fill in long periods between clear Landsat images in cloud-prone regions due to insufficient revisit time of Landsat series for ET mapping.

VIIRS 08/04/2013

VIIRS METRIC ET_{r,F} 08/04/2013

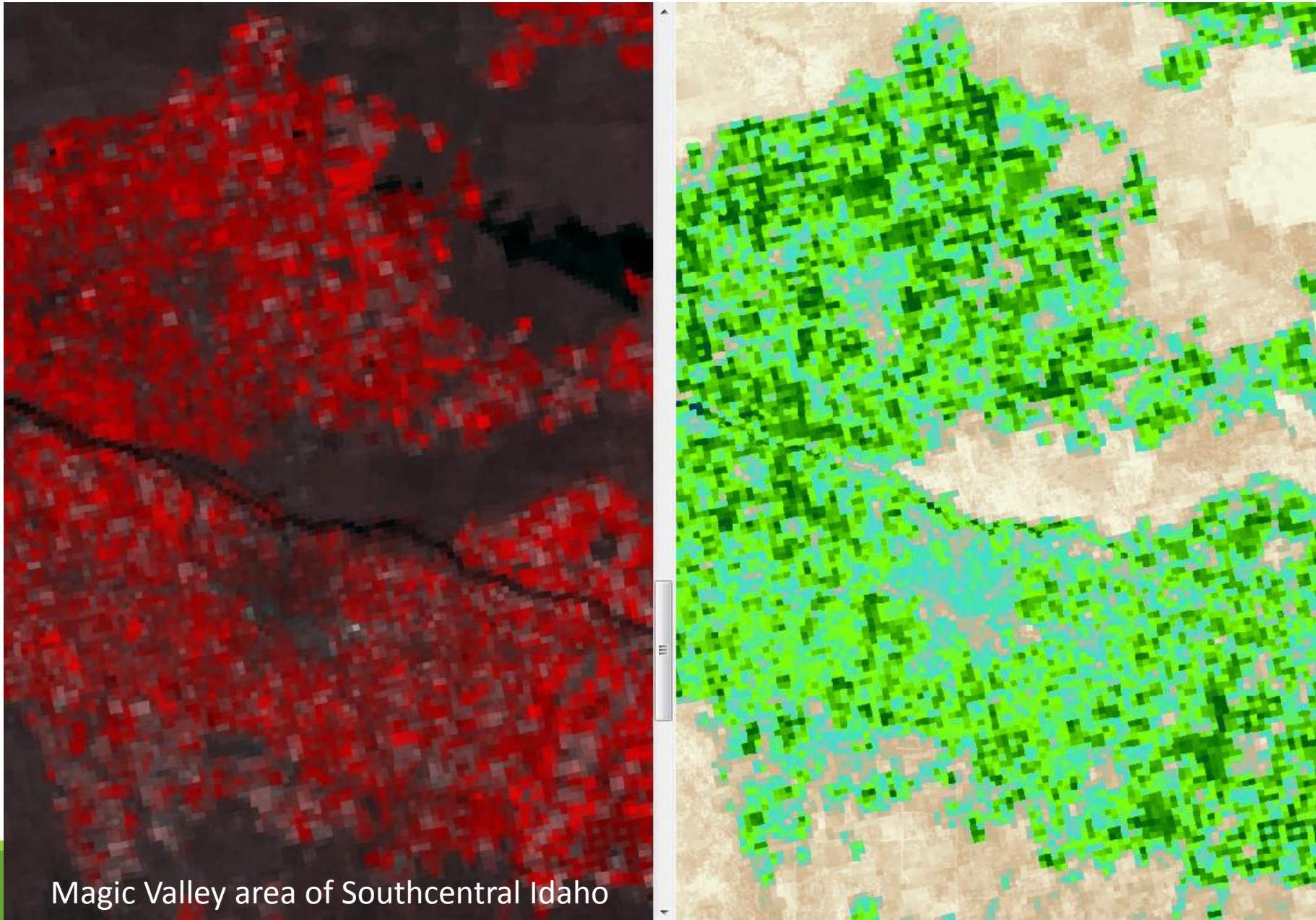


Magic Valley area of Southcentral Idaho

VIIRS 08/04/2013

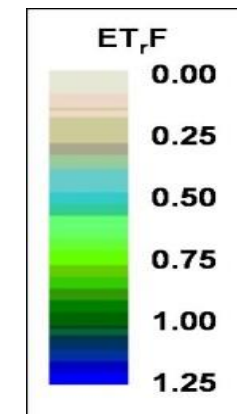
VIIRS METRIC ETrF 08/04/2013

False Color and ETrF in original projection and registration



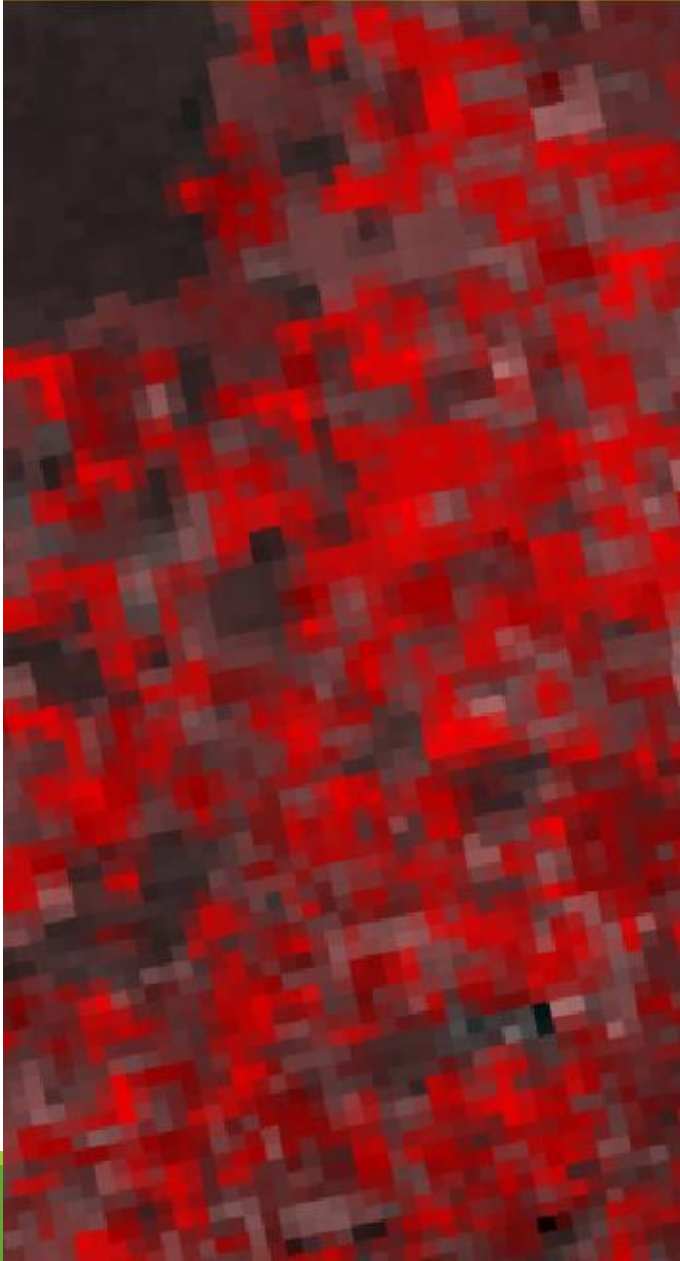
Comment:

- VIIRS I-bands work well to produce ET via Surface Energy Balance.
- Large pixel size (~375 m) makes fidelity of individual fields challenging
- Accurate registration and handling is essential.

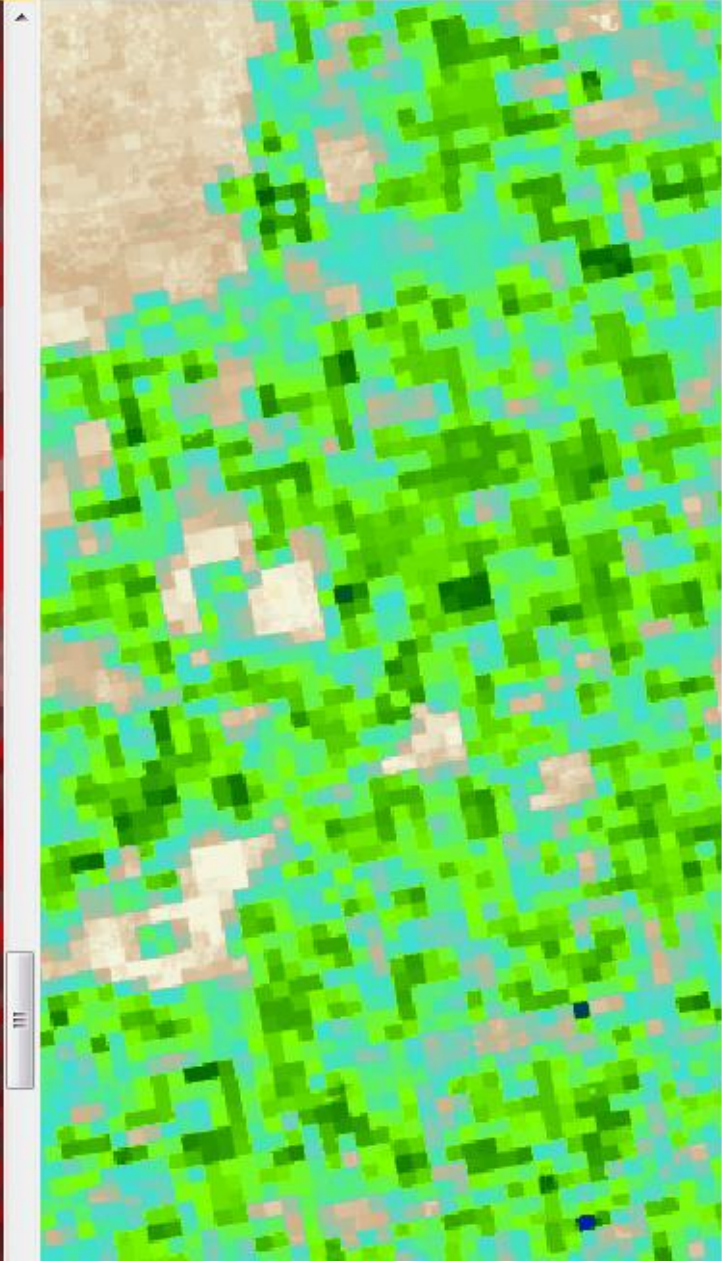


Definitely, VIIRS is not a replacement for Landsat for field-scale ET. However, we consider it when the Landsat record is insufficient due to clouds

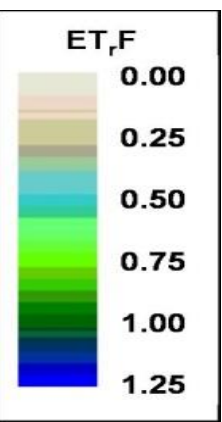
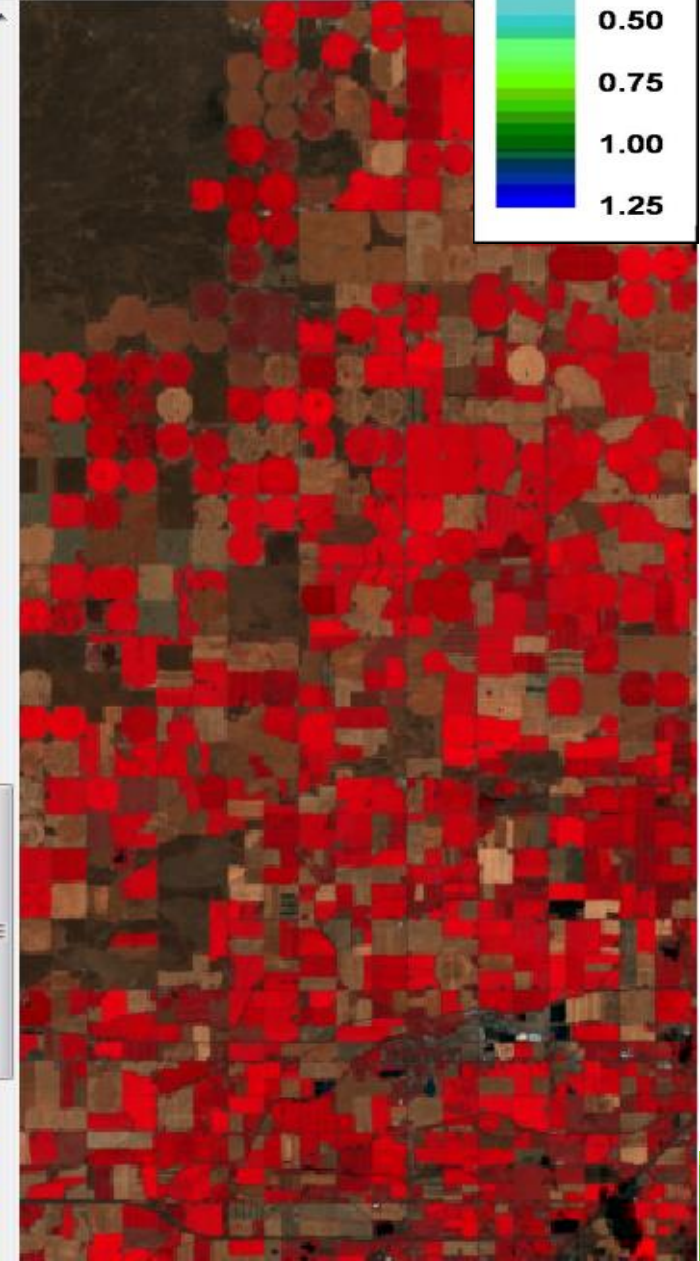
VIIRS 08/04/2013



VIIRS METRIC ETrF 08/04/2013



Landsat 08/10/2013



Problems using Standard Software and Reprojection at the ~375 m scale

ENVI / ArcGIS / ERDAS Imagine / GDAL Tools

(We were not able to use ERDAS Imagine to load NPP/VIIRS HDF5 datasets)

NPP/VIIRS products were downloaded from
<http://www.class.ncdc.noaa.gov/saa/products/>
JPSS Visible Infrared Imaging Radiometer Suite Sensor Data Record (VIIRS_SDR)

VIIRS Imagery Band 01 SDR (SVI01) (public 02/07/2012)

VIIRS Imagery Band 02 SDR (SVI02) (public 02/07/2012)

VIIRS Imagery Band 03 SDR (SVI03) (public 02/07/2012)

VIIRS Imagery Band 04 SDR (SVI04) (public 02/07/2012)

VIIRS Imagery Band 05 SDR (SVI05) (public 02/07/2012)

VIIRS Image Bands SDR Ellipsoid Terrain Corrected Geolocation (GITCO) (public 02/07/2012)

When downloaded from the Class system as a group, the products come in HDF5 datasets, 2 datasets for each image: GIMGO-SVI01-SVI02-SVI03-SVI04-SVI05_npp_d20160615.....h5 and GITCO_npp_d20160615.....h5.

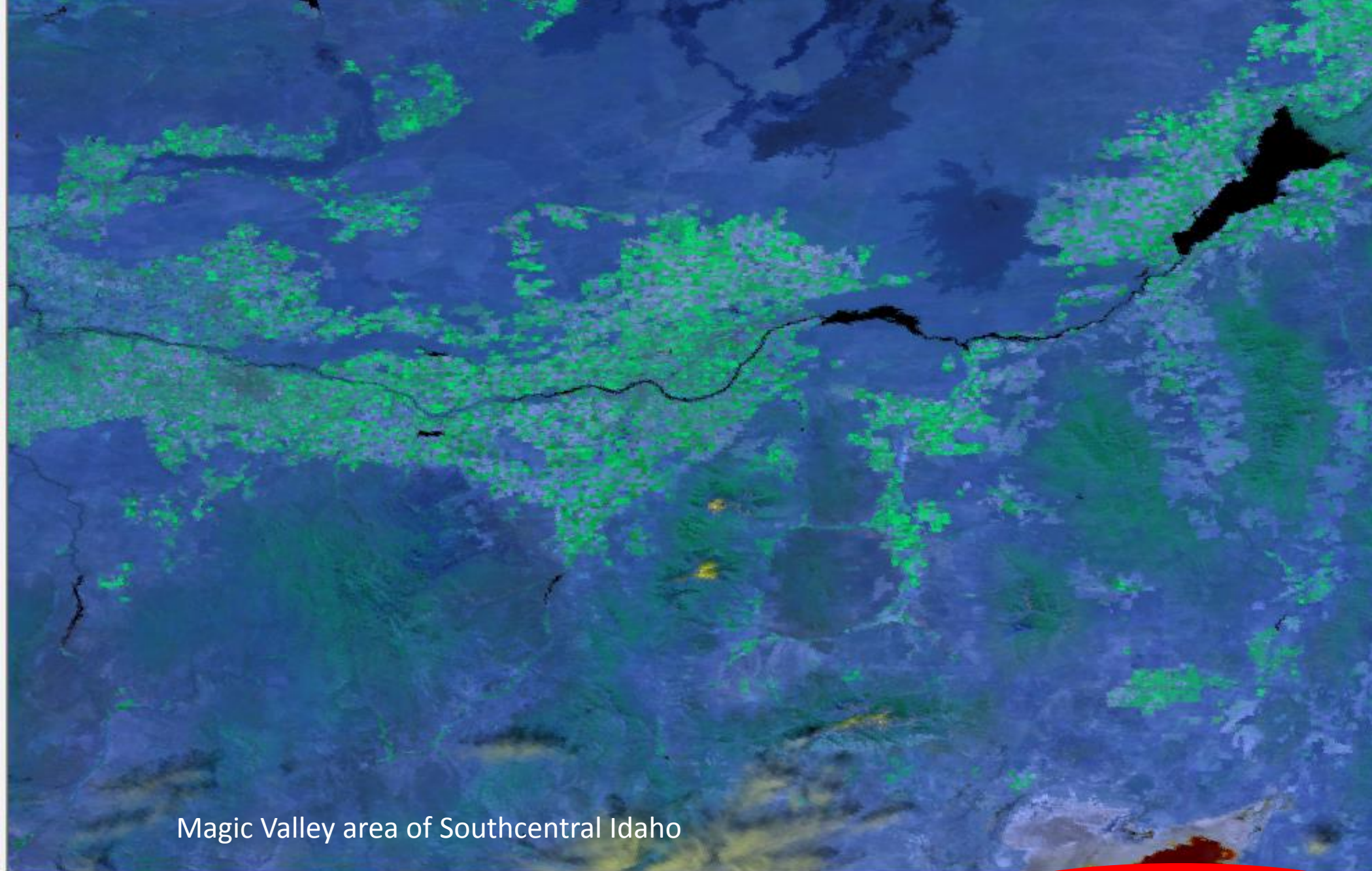
We take the radiance, reflectance, and brightness temperature from the GIMGO data file.

The geolocation information used comes from the GITCO data file. The GIMGO geolocation file is a projection onto smooth ellipsoid (WGS84 ellipsoid) and the GITCO geolocation file is parallax-corrected for terrain.

We limit the images we download to those with sensor view angles less than 15 degrees.

VIIRS geolocation data and products are 'point data' representing pixel centers. Each 'pixel' can have a unique size and shape.

SVI Products are presented as nonregistered arrays.

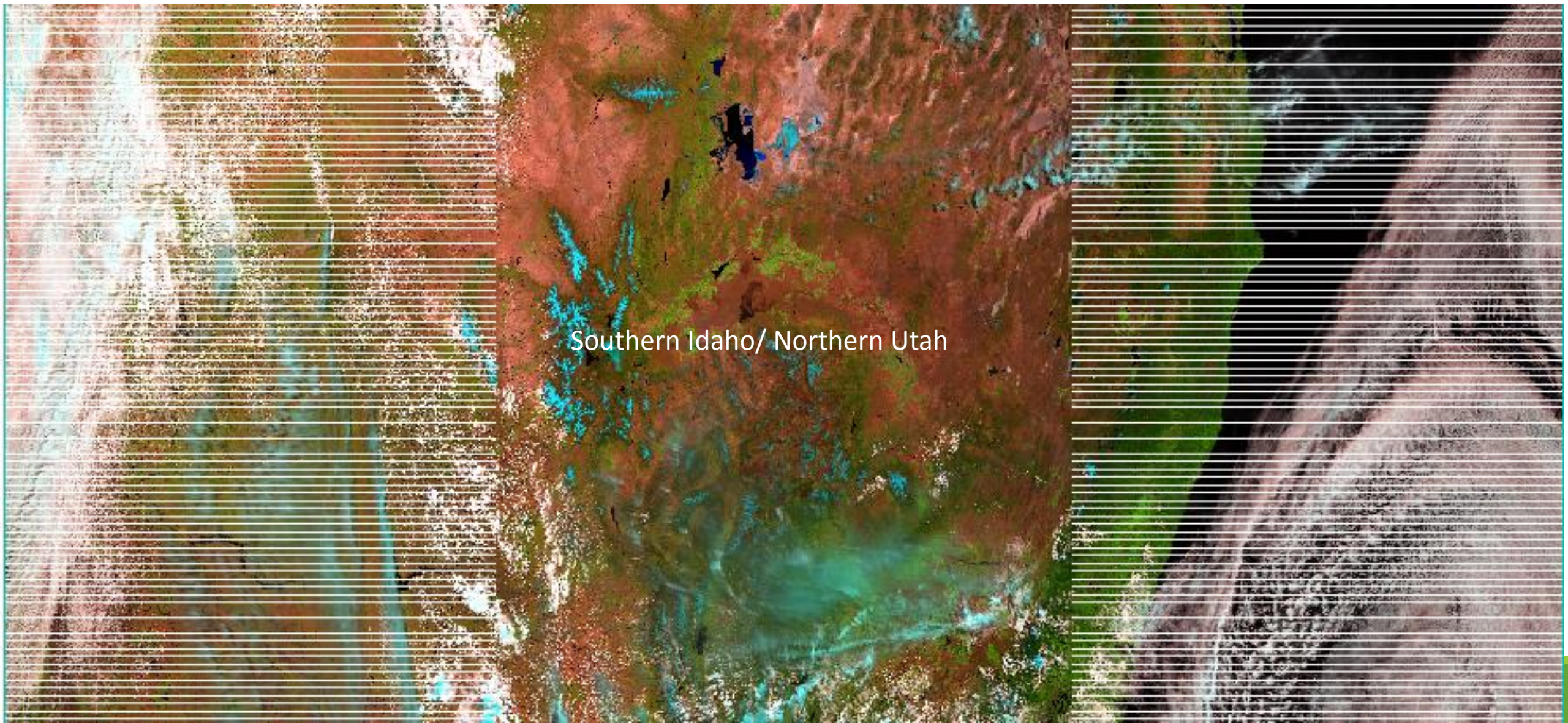


Magic Valley area of Southcentral Idaho

ArcGIS Import results in image being positioned on the wrong hemisphere.

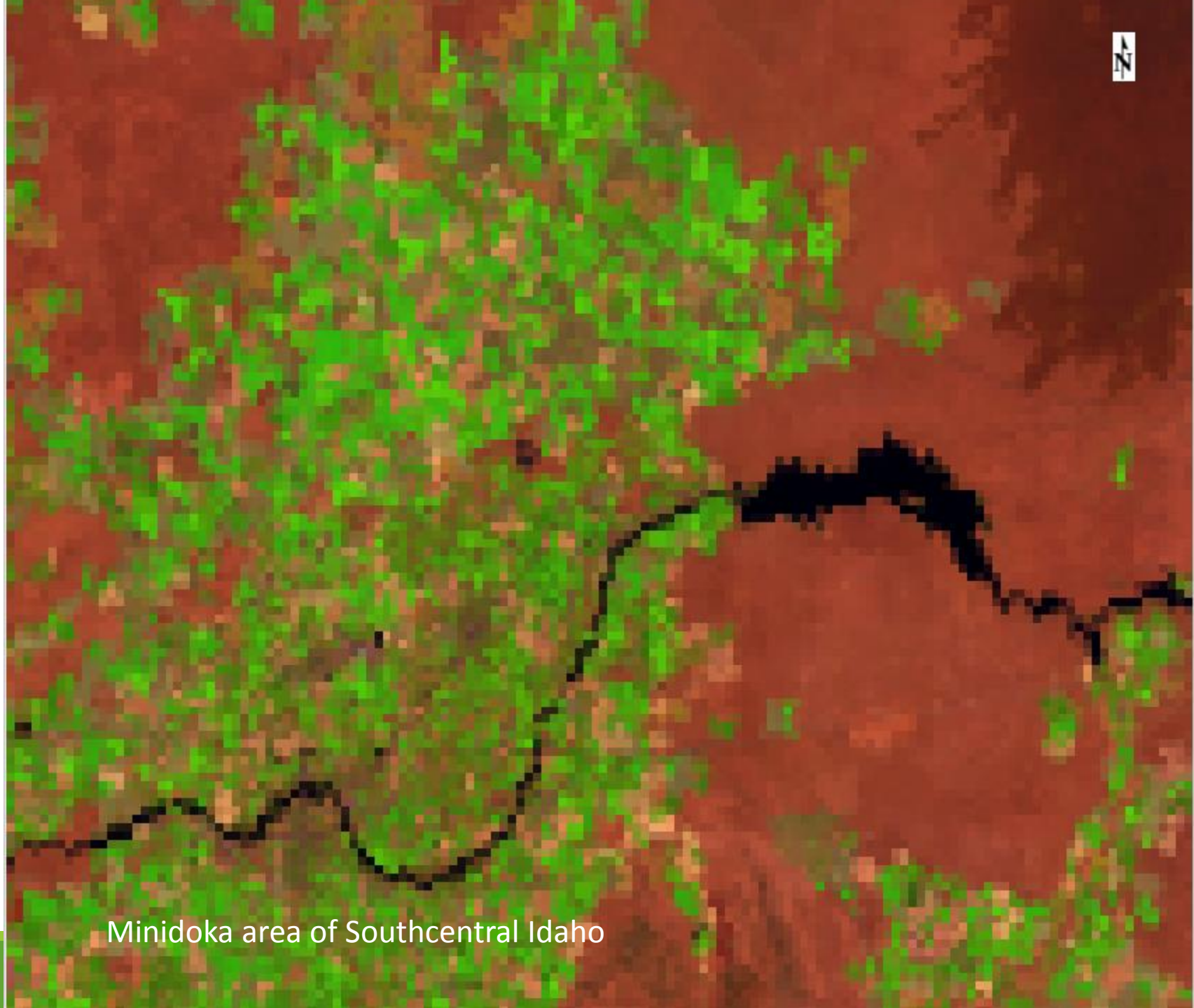
67.045 41.727 Decimal Degrees

Loading the raw VIIRS image into **ENVI** without geolocation produces an inverted image.
Geolocation of pixels is not defined



When using the ENVI geolocation/reprojection tool, original VIIRS pixels are rotated, resized, and **resampled** at ~375 m using NN. Original pixel units are in degrees

Later further reprojection and resampling to 30 m UTM and (Idaho) IDTM 83 produces an apparent shift when compared with Landsat 8 as shown in following slides.



Minidoka area of Southcentral Idaho

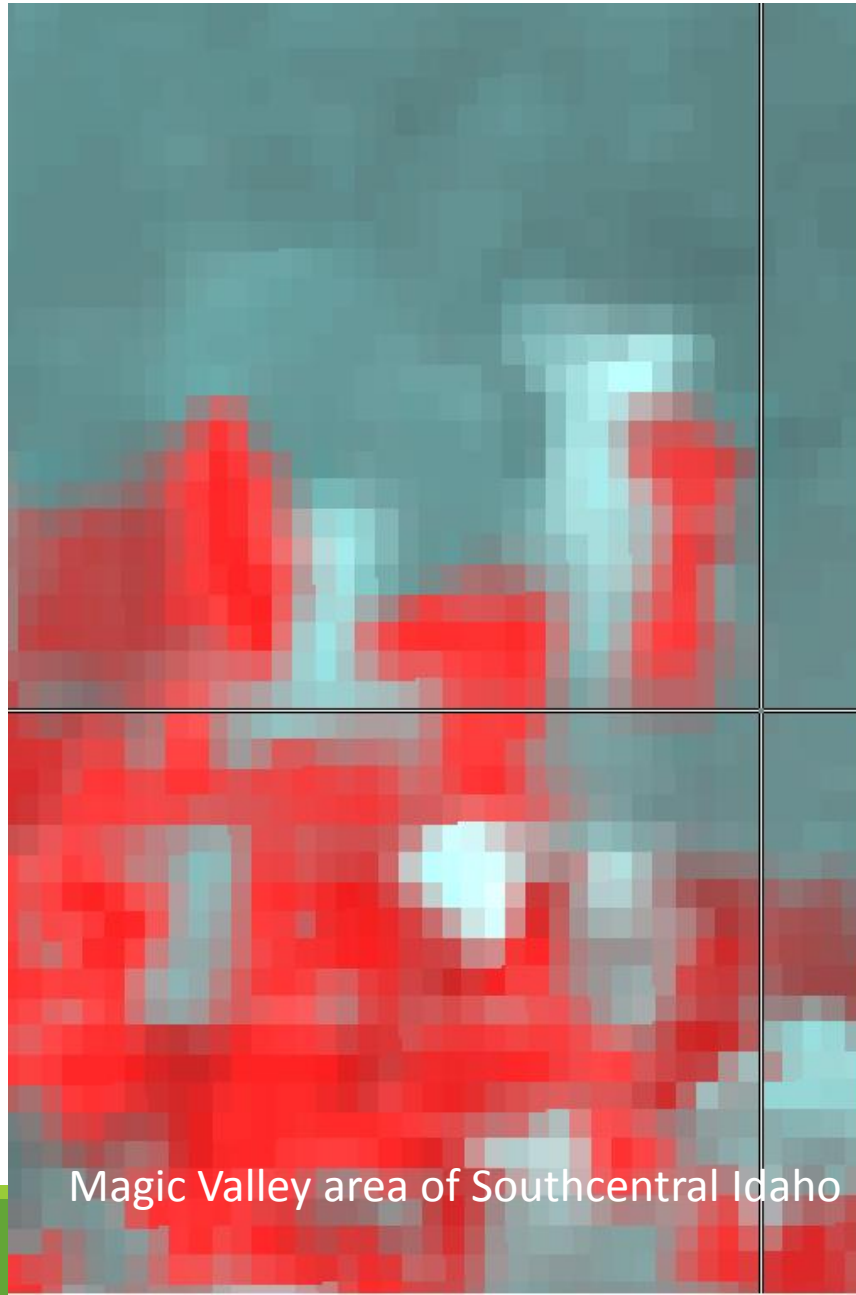
VIIRS - 08/04/2013

LANDSAT 8 08/10/2013

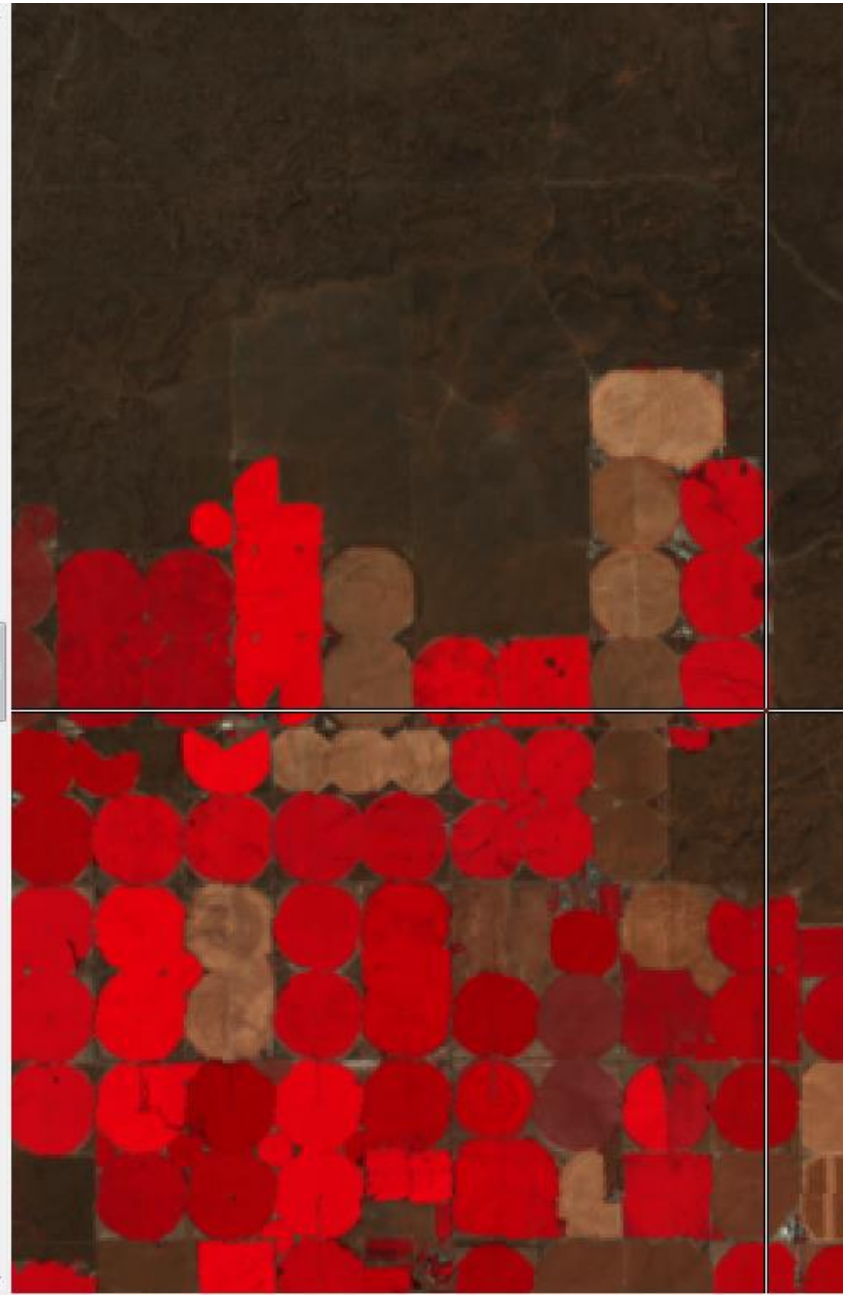
Comment:

In 'standard' projection, pixels are resized (to square 375 m), oriented N-S, and shifted using NN (typical, standard resampling).

Besides losing spatial fidelity at the 400 m scale, a shift bias can occur.



Magic Valley area of Southcentral Idaho



Conclusion:

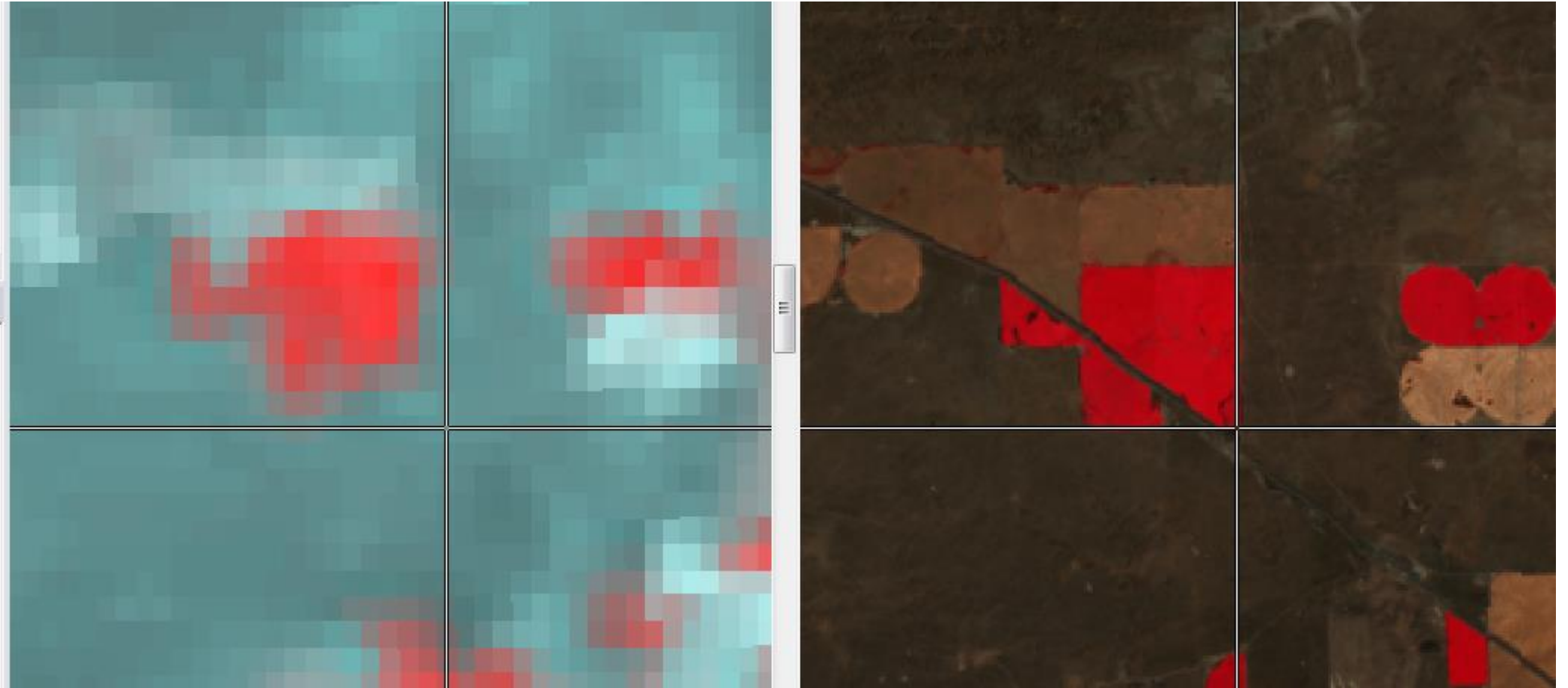
Projection with resampling at ~375 m produces sufficient error to disqualify utility of VIIRS for integration with Landsat imagery.

This occurs even without the bias shifts that occur, due to NN shifting of original ~375 m pixels.

Cross-hairs have identical coordinates

VIIRS - 08/04/2013

LANDSAT 8 08/10/2013

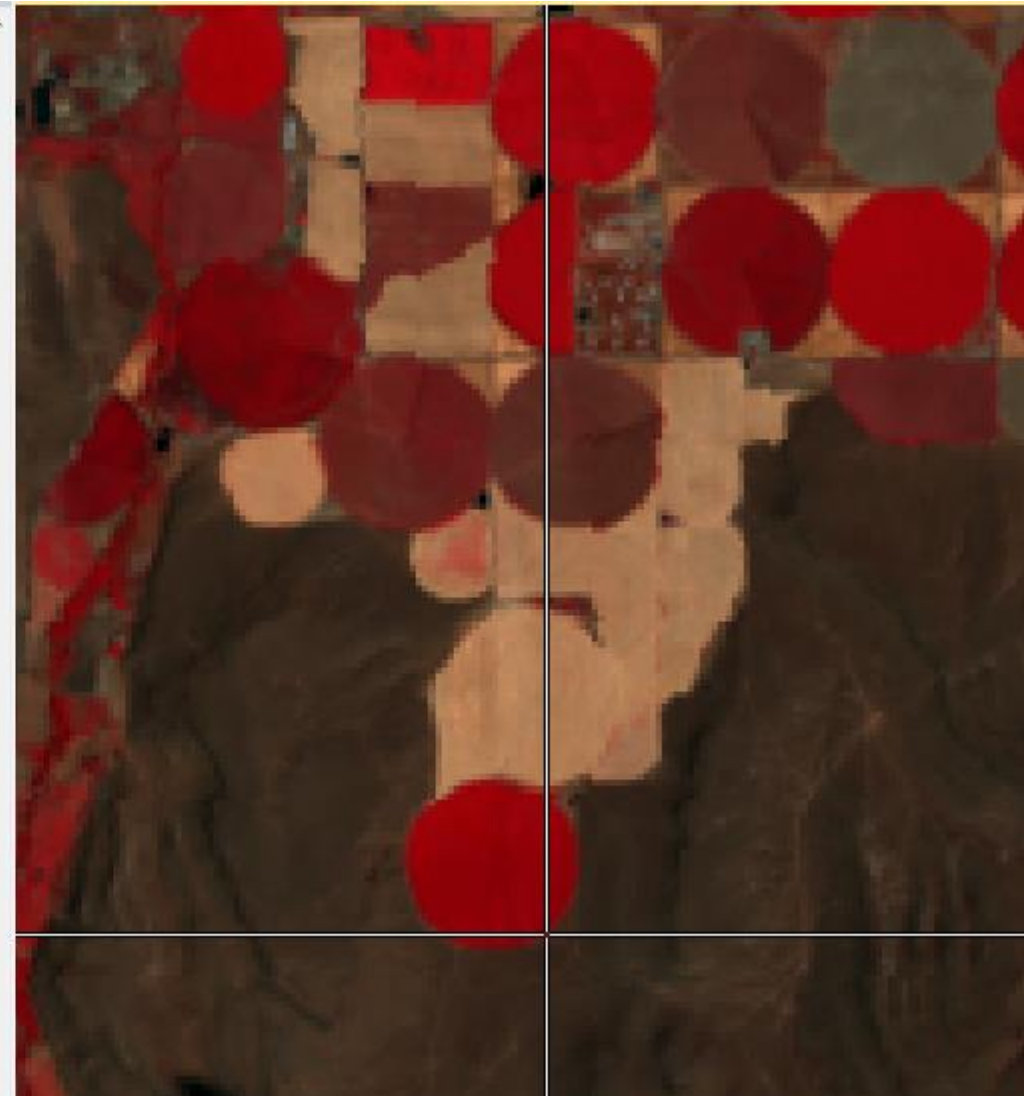


Magic Valley area of Southcentral Idaho

VIIRS - 08/04/2013



LANDSAT 8 08/10/2013

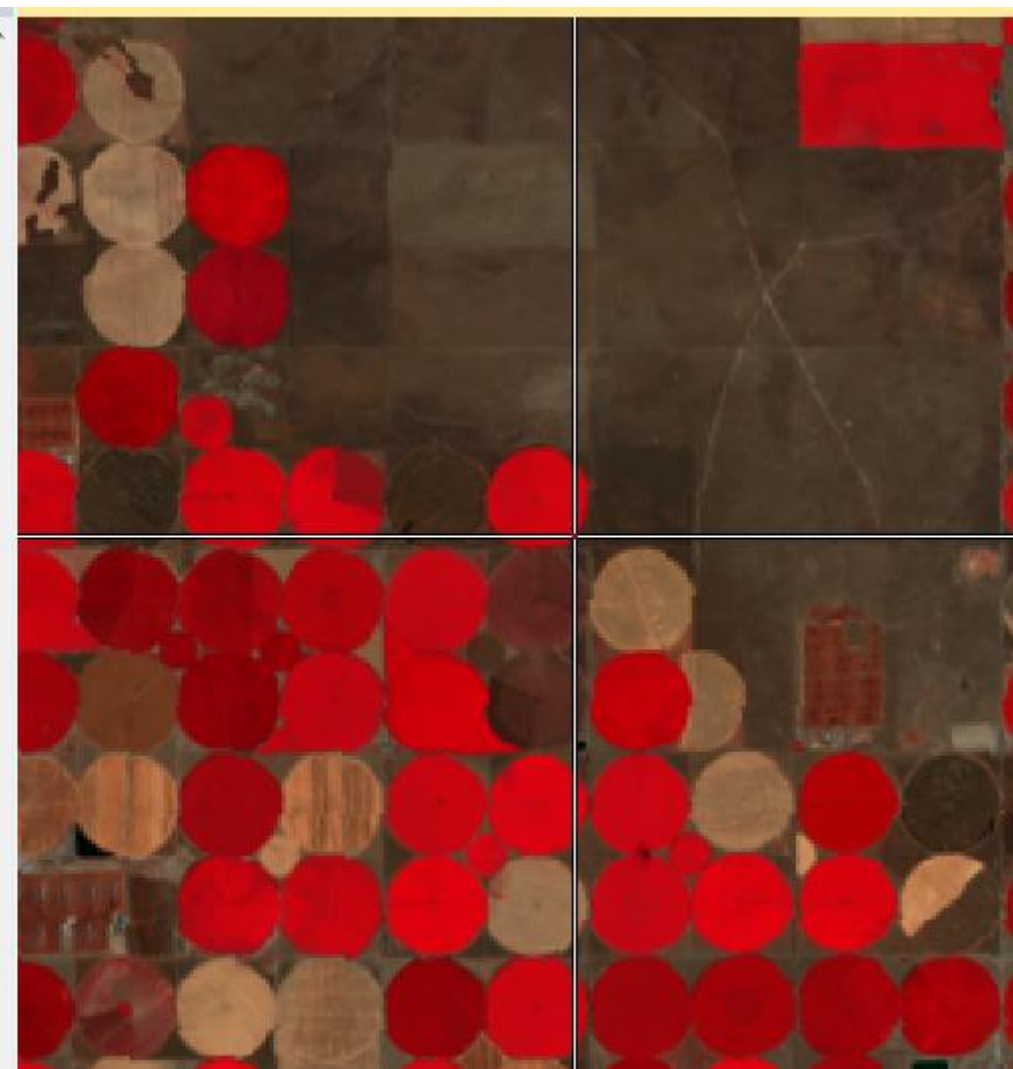
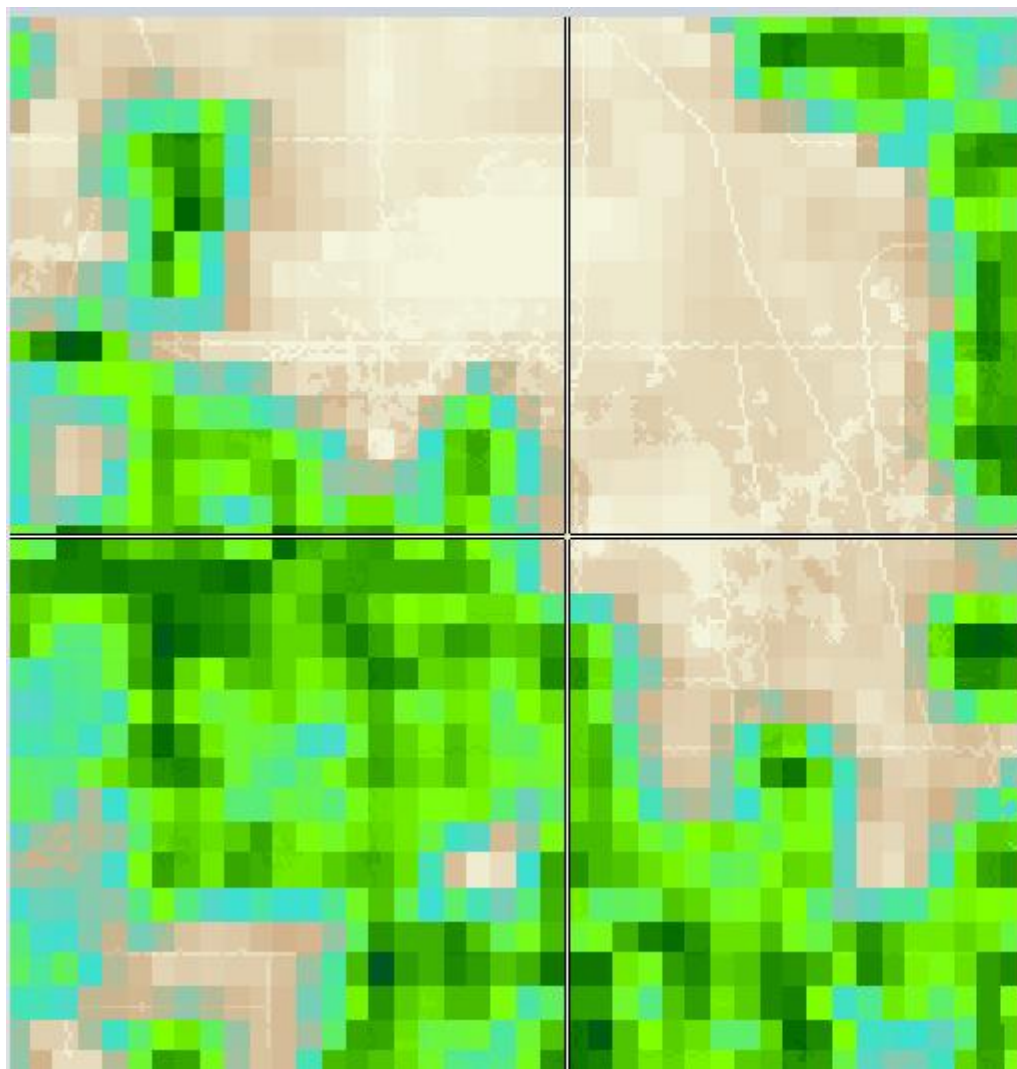


Magic Valley area of Southcentral Idaho

VIIRS ETrF - 08/04/2013

LANDSAT 8 08/10/2013

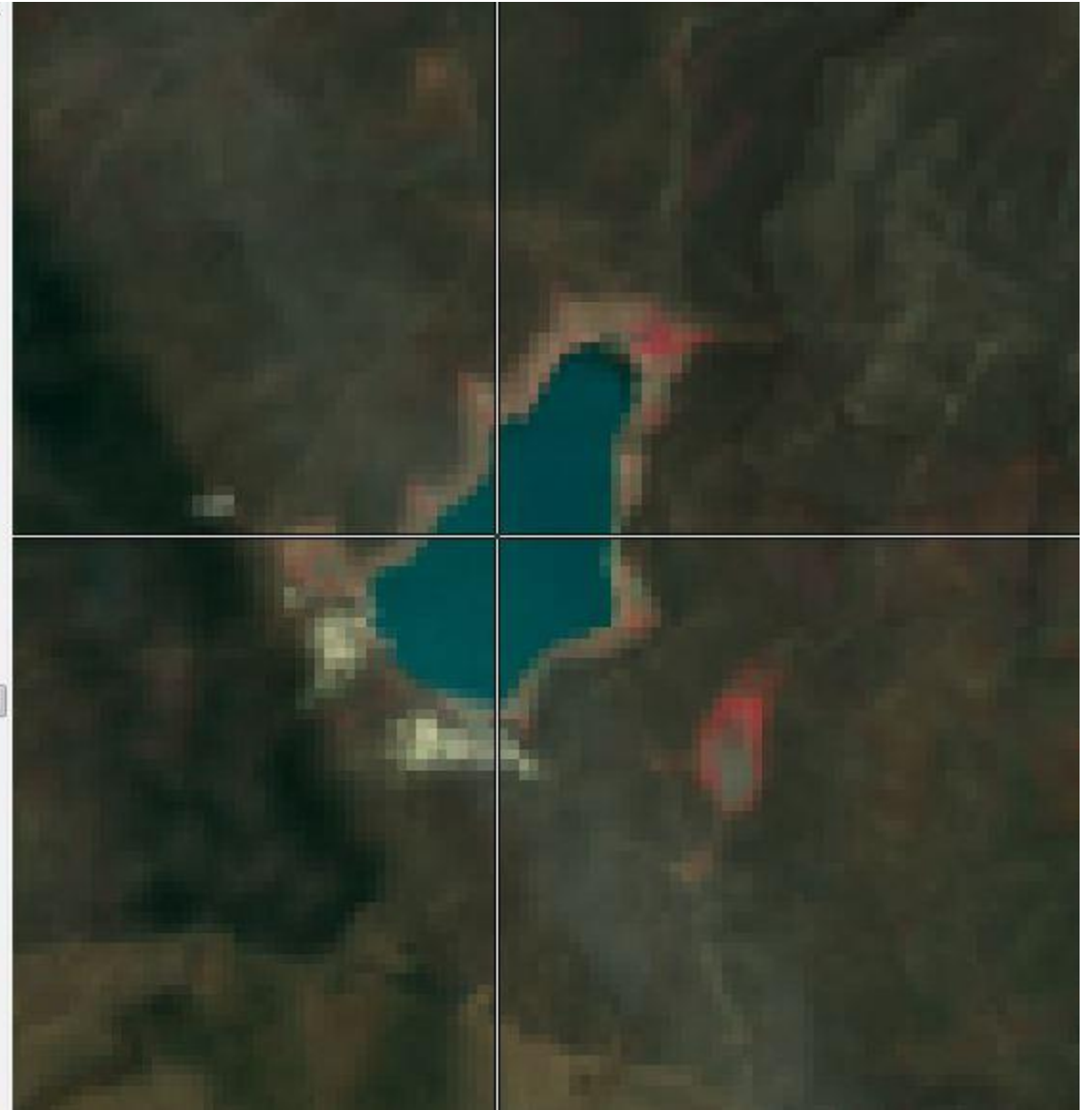
Conclusion:
NN-shifted
blockiness and/or
shift bias transfers
into the ET
retrieval



Idaho Homebrew Registration of VIIRS

1. Using Python Osgeo-gdal, Numpy, H5py and pyproj libraries, find the VIIRS Geographic bounding envelope associated with the following constraints:
 - a) View angle,
 - b) Latitude
 - c) Longitude
 - numpy
 - Osgeo-GDAL
 - pyproj
 - H5py
2. Based on the bounding envelope's geographic coordinates, compute the coordinates of the associated bounding envelope in the desired projection (UTM, IDTM, ...).
3. Create two 1-D matrices with 30m spacing, one for the easting (x) coordinate and one for the northing (y) coordinate of the destination image with 30m resolution. Compute the easting (x) and northing (y) coordinates for each 30 m cell in the destination image. Based on the x and y coordinates, compute the associated longitude and latitude of each cell in the destination image.
4. For each cell of the destination image, determine the VIIRS pixel to use:
 - a) Compute the geodesic distance to VIIRS pixels using the GITCO longitude and latitude HDF arrays.
 - b) Find the minimum geodesic distance
 - c) Determine the VIIRS HDF array row and column pointers associated with the minimum distance
 - d) Save the HDF row and column pointers for the destination cell.
 - e) If there are multiple HDF pixels qualifying, pick the first one found.
5. For each band desired, create a grid using the projected envelope and cell spacing. Using the HDF pixel coordinates saved, load the HDF band data into the 30 m grid cell.

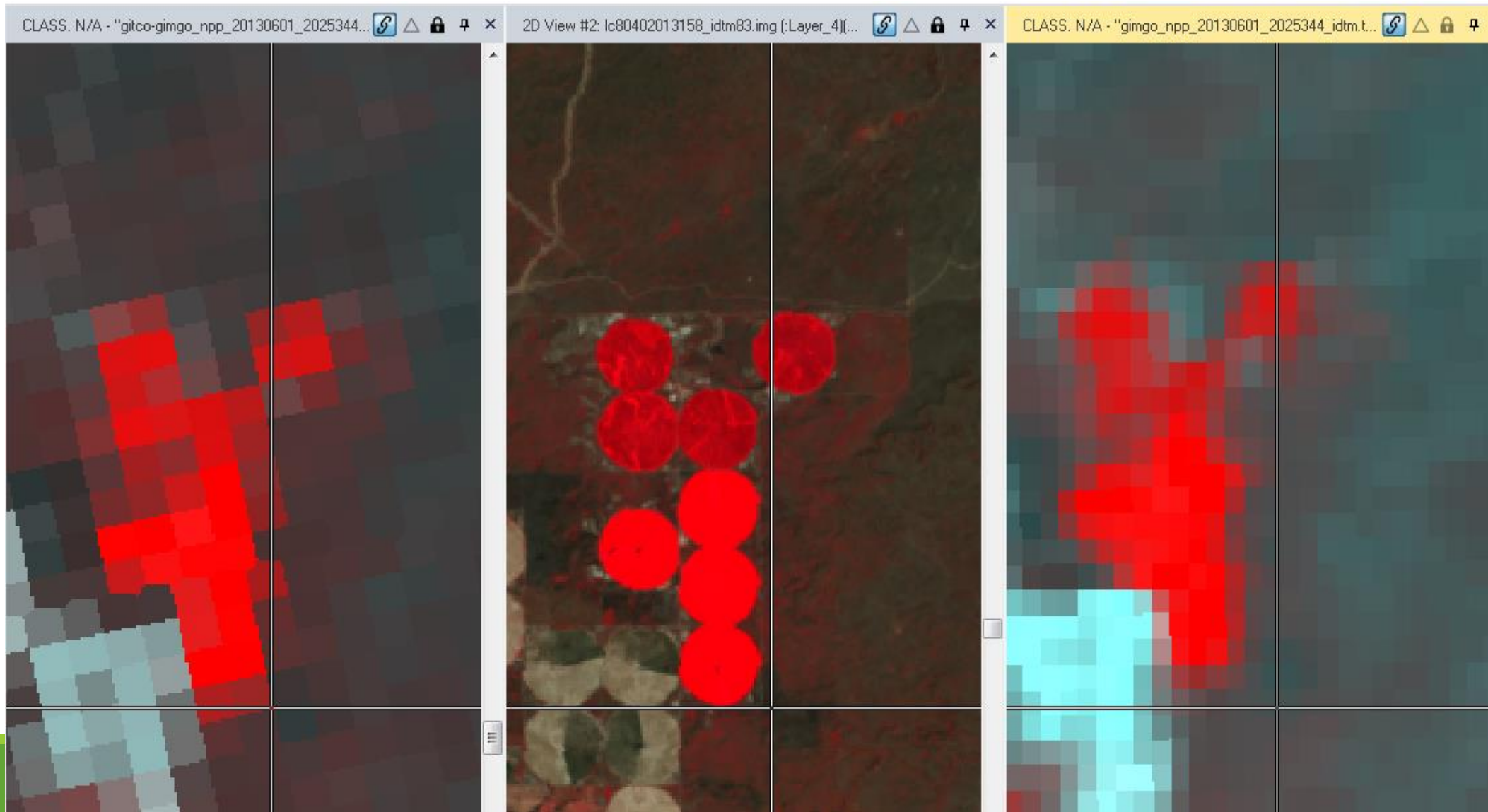
The Homebrew method preserves original
VIIRS "pixels" via 30 m breakdown and
assignment of registration



Idaho Homebrew Procedure
VIIRS 08/04/2013

Landsat
(08/10/2013)

Distributed GDAL tools
VIIRS H5 data sets 08/04/2013 using
OsGeo-GDAL geolocation and resampling tools
(gdaltransform.exe and gdalwarp.exe)

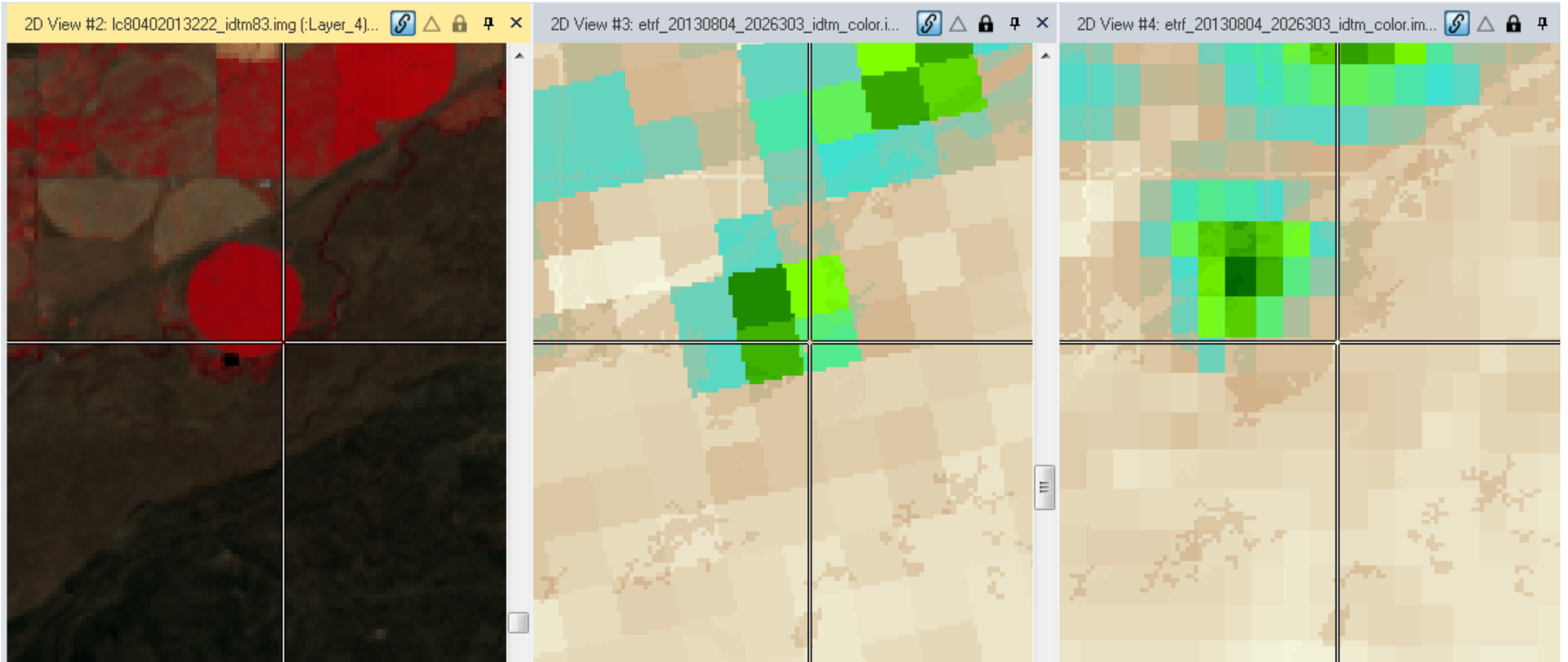


Landsat 08/10/2013

VIIRS 08/04/2013 (homebrew projection)

VIIRS 08/04/2013 (Std. projection to
~200 m)
METRIC ETrF

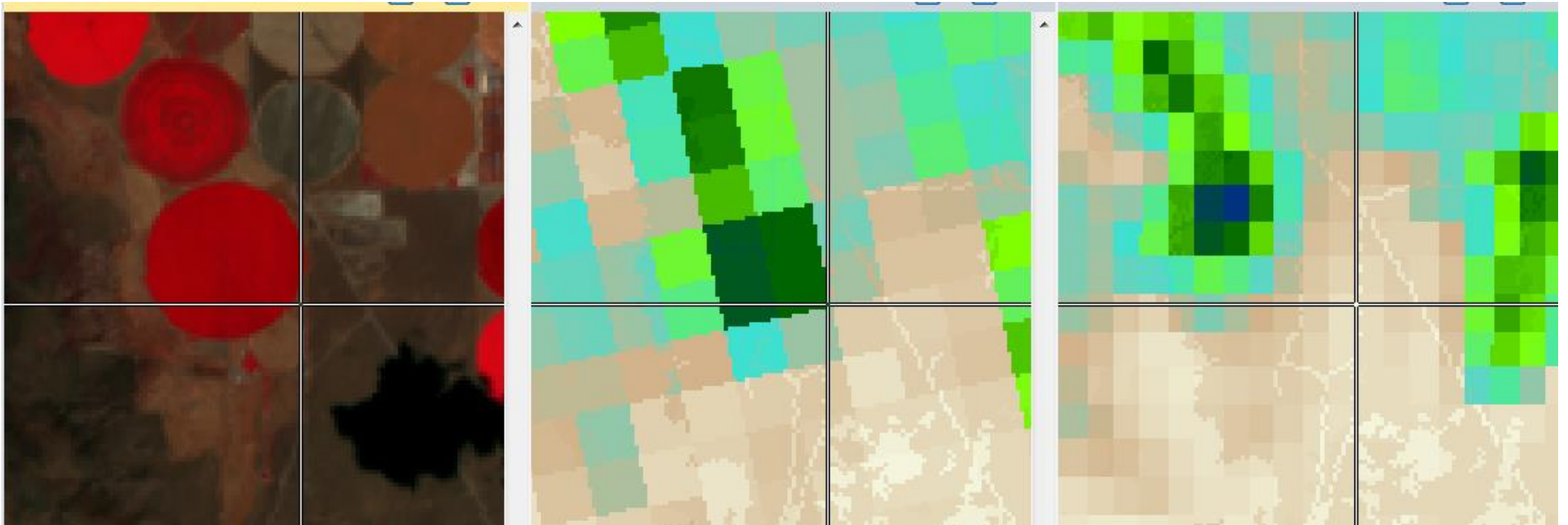
METRIC ETrF



Landsat 08/10/2013

VIIRS 08/04/2013 (homebrew projection)

VIIRS 08/04/2013 (Std. projection to
~200 m)

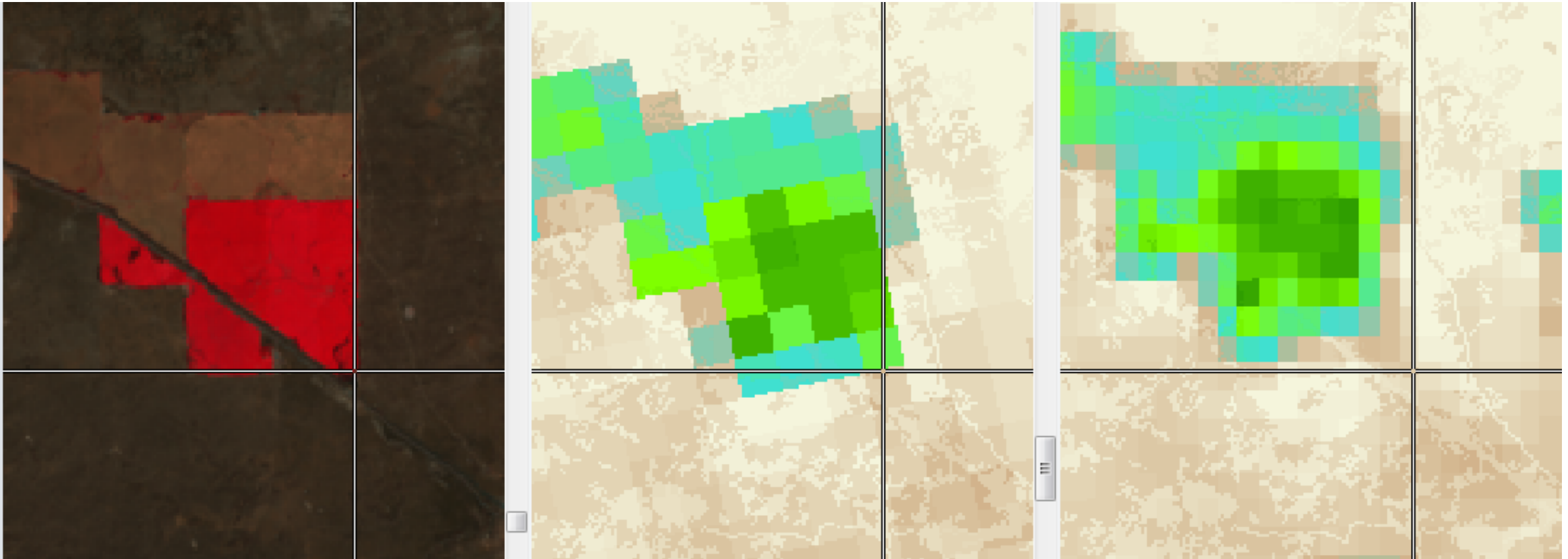


Landsat 08/10/2013

VIIRS 08/04/2013 (homebrew projection)

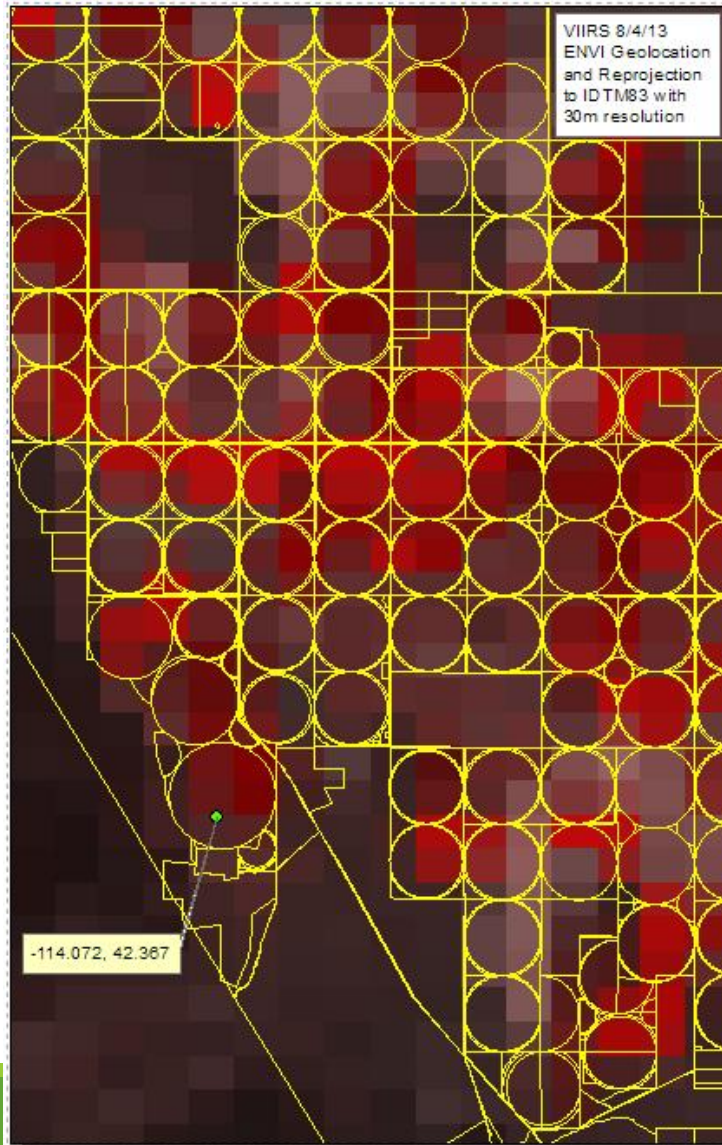
VIIRS 08/04/2013 (Std. projection to
200 m)

Conclusion: GITGO registration information is accurate. Standard projection tools with NN resampling at near-native VIIRS pixel size causes shifts in information that are intolerable for meshing with Landsat.

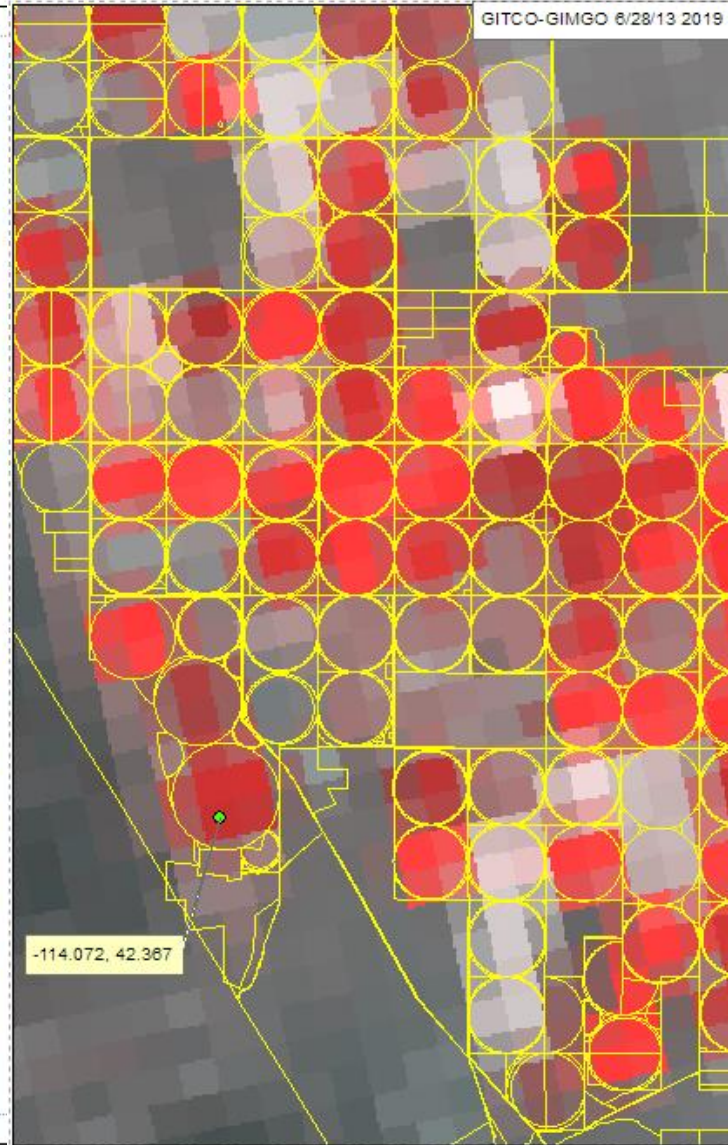


Conclusion: GITGO registration information is accurate. Standard projection tools with NN resampling at near-native VIIRS pixel size causes shifts in information that are intolerable for meshing with Landsat.

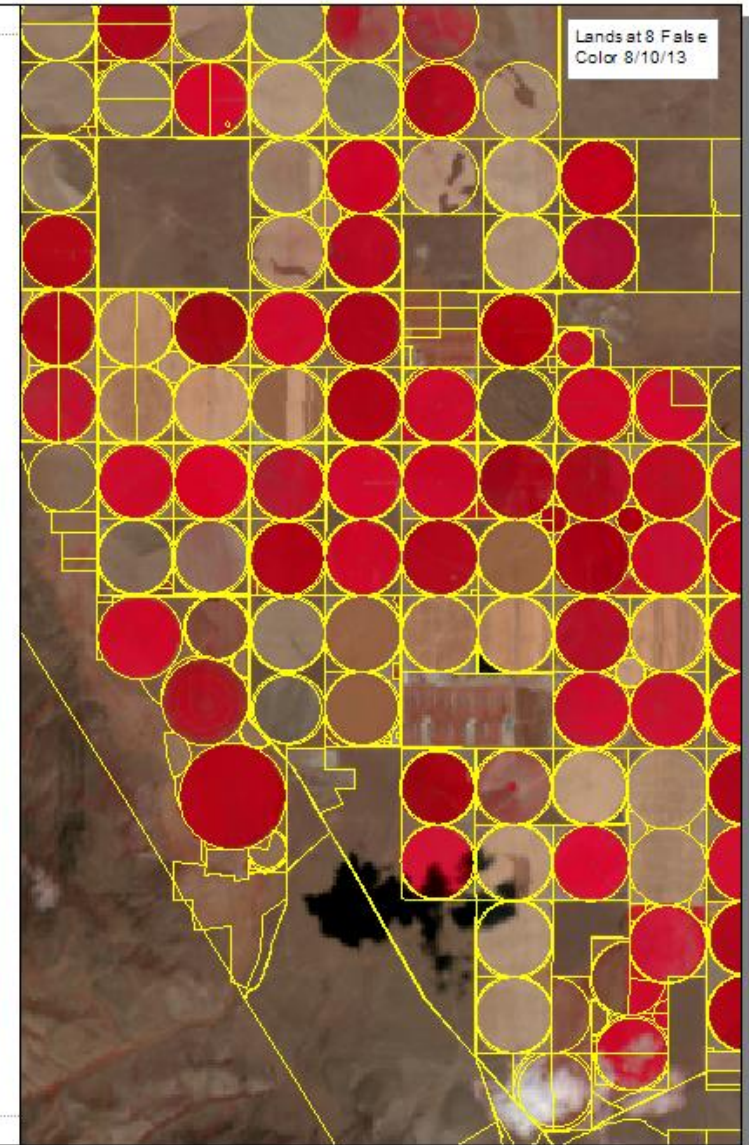
VIIRS 08/04/2013 (Std. ENVI
projection at 30 m)



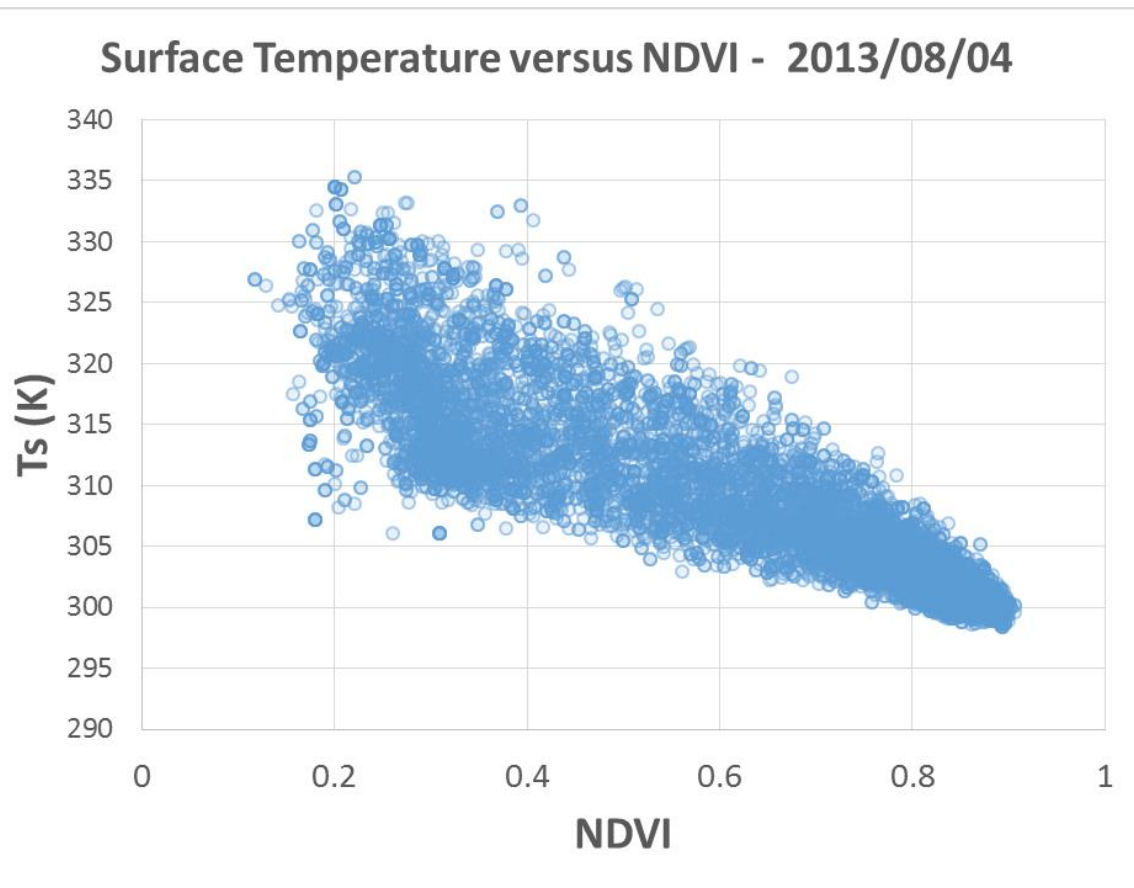
VIIRS 06/28/2013 (homebrew
projection)



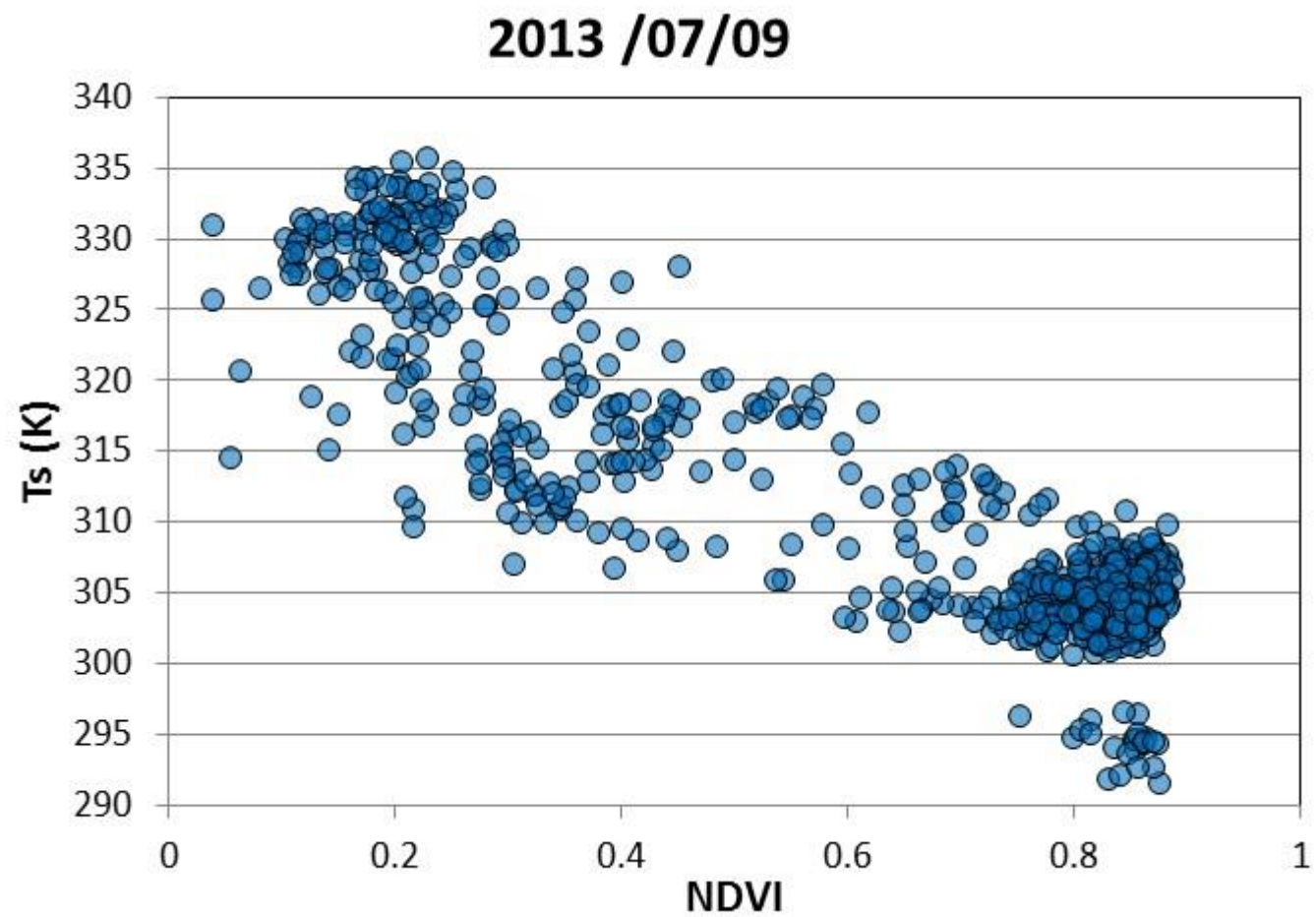
Landsat 08/10/2013



VIIRS following 30 m Idaho Homebrew Resampling

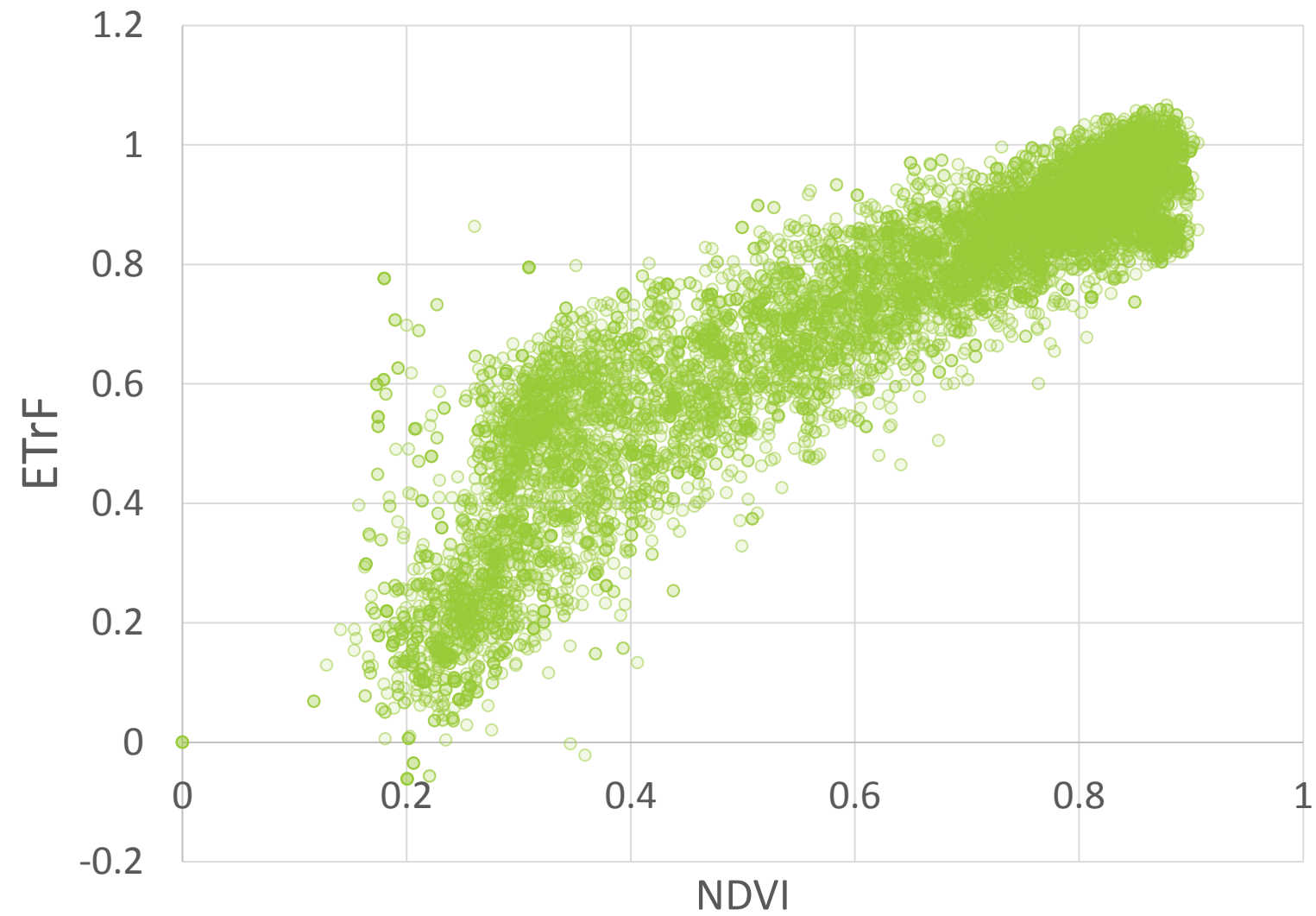


Landsat 8 TIRS/OLI



Good similarity in relationships between LST and NDVI indicating consistent performance across bands

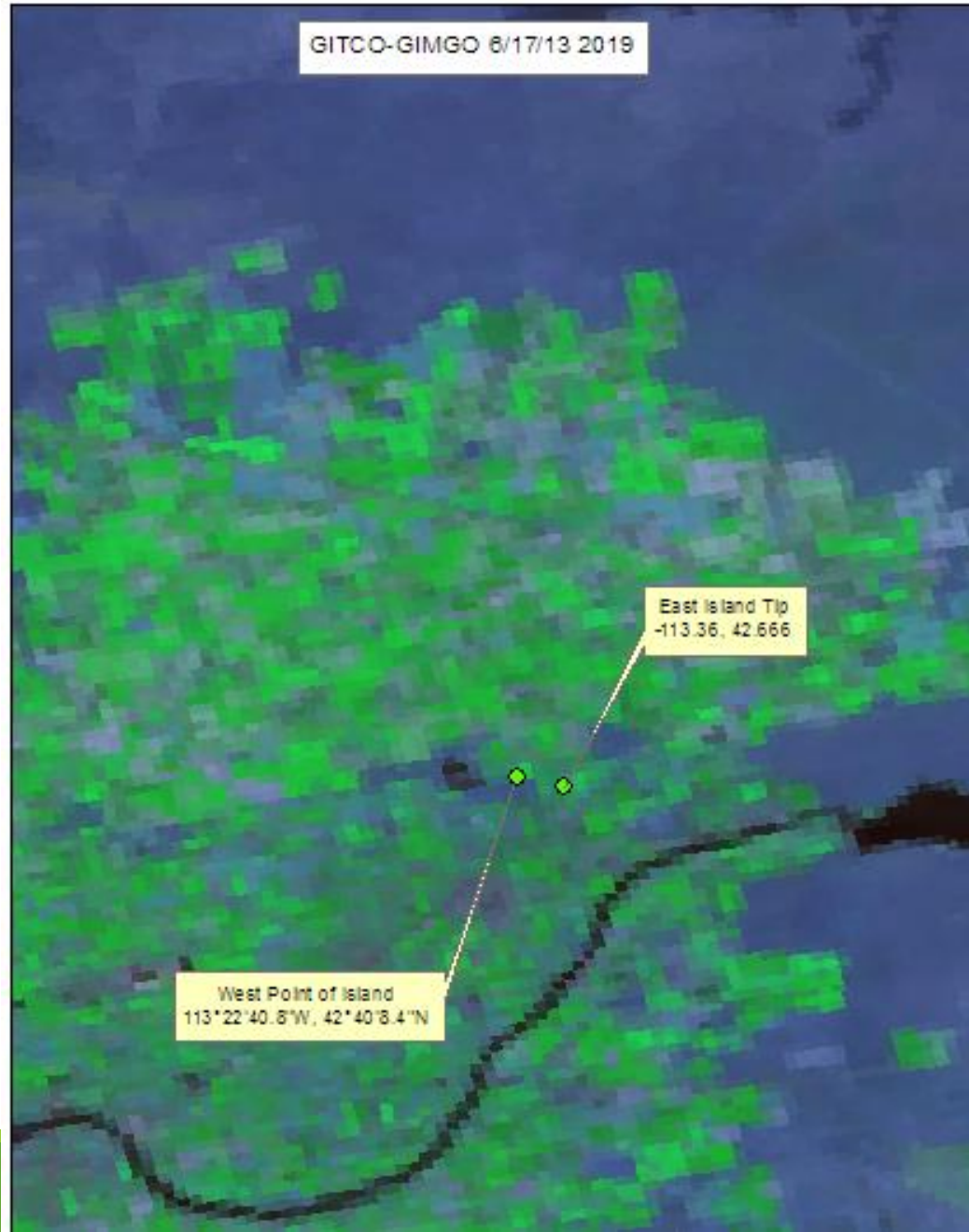
ETrF versus NDVI - 2013/08/04



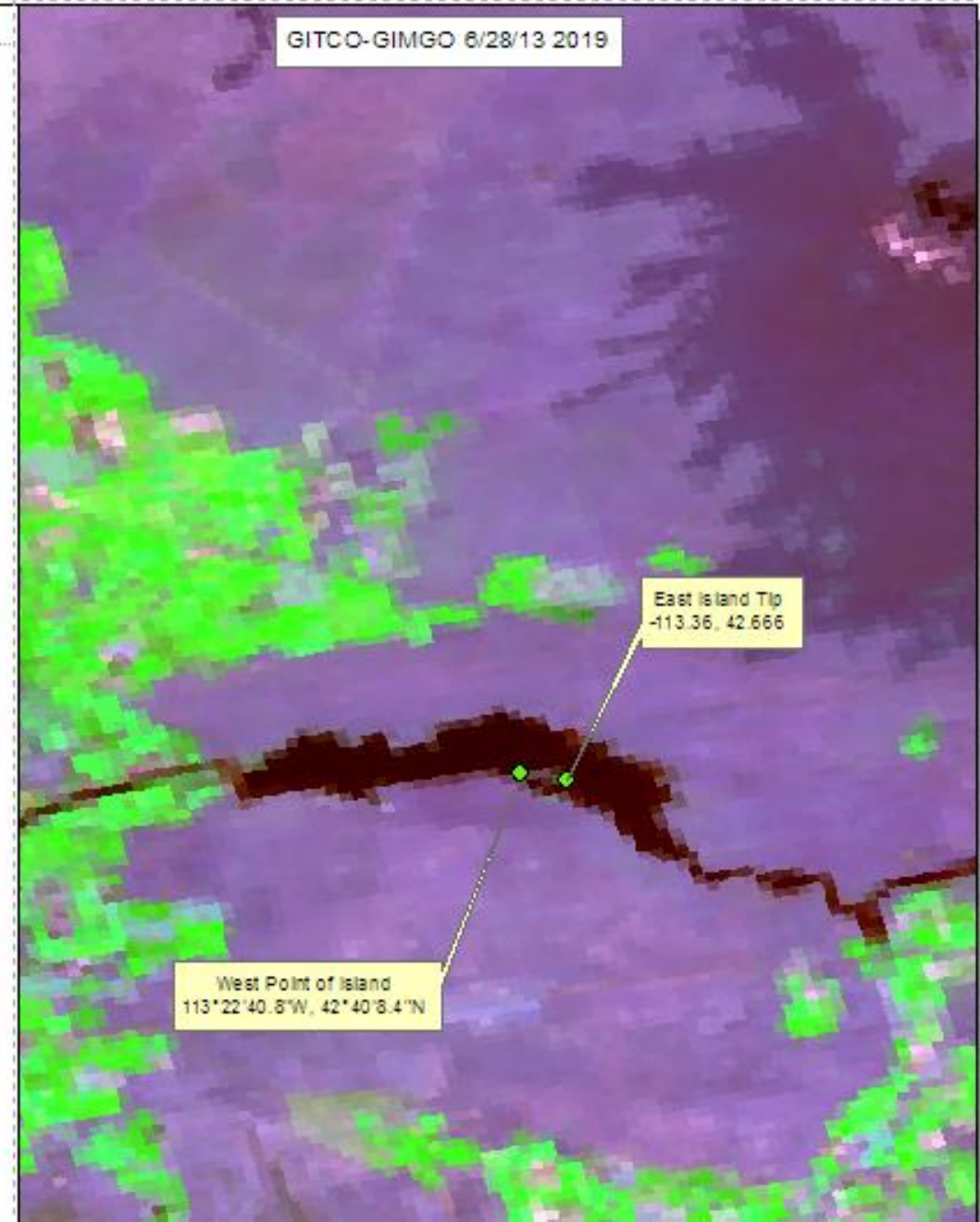
Caution: NNP/VIIRS Geolocation Arrays are sometimes totally incorrect

Case: Incorrect geolocation arrays on the June 17, 2013 overpass for southern Idaho were approximately 20 km offset to the west-northwest as shown in the following two slides.

Incorrect 6/17/13

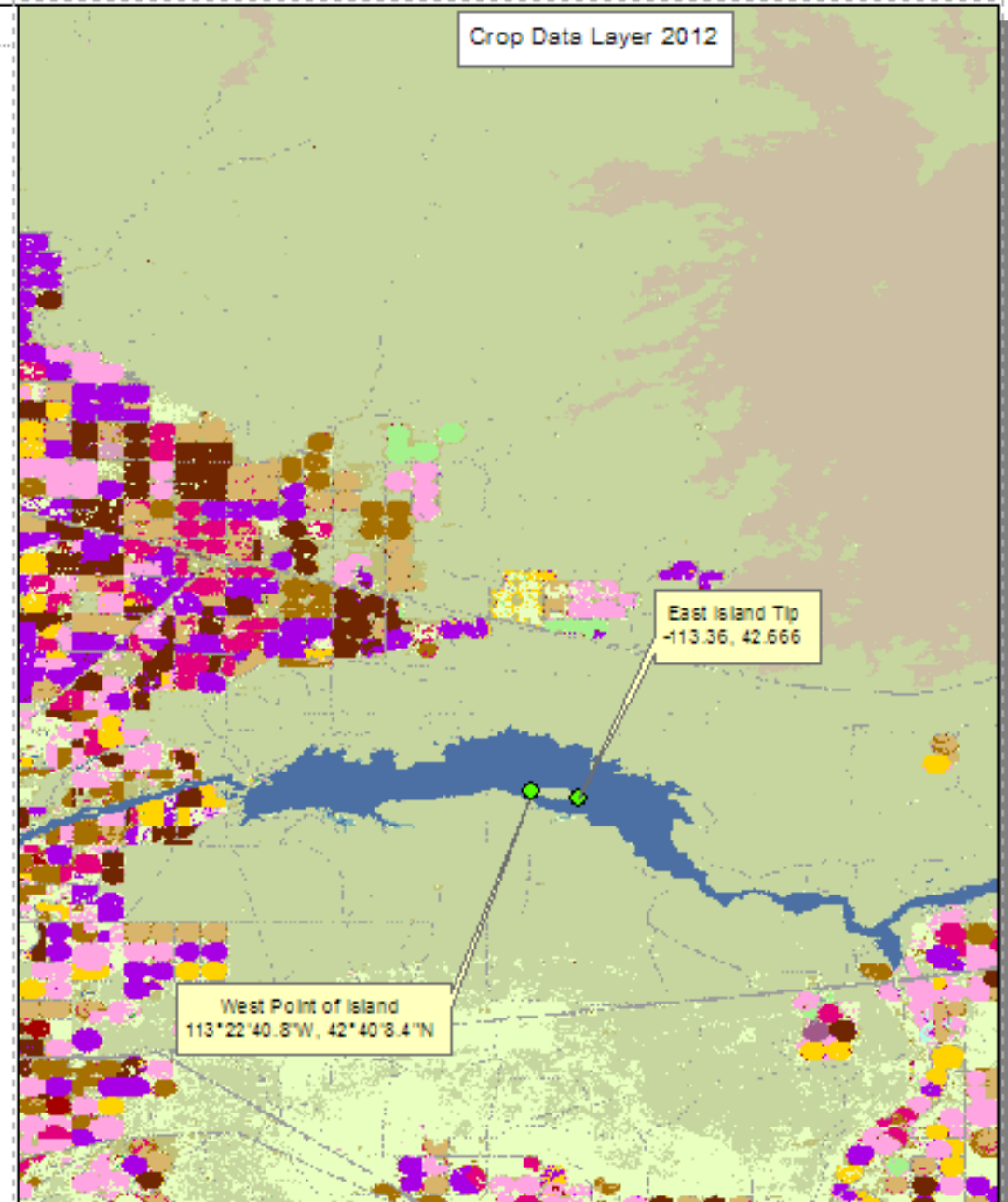
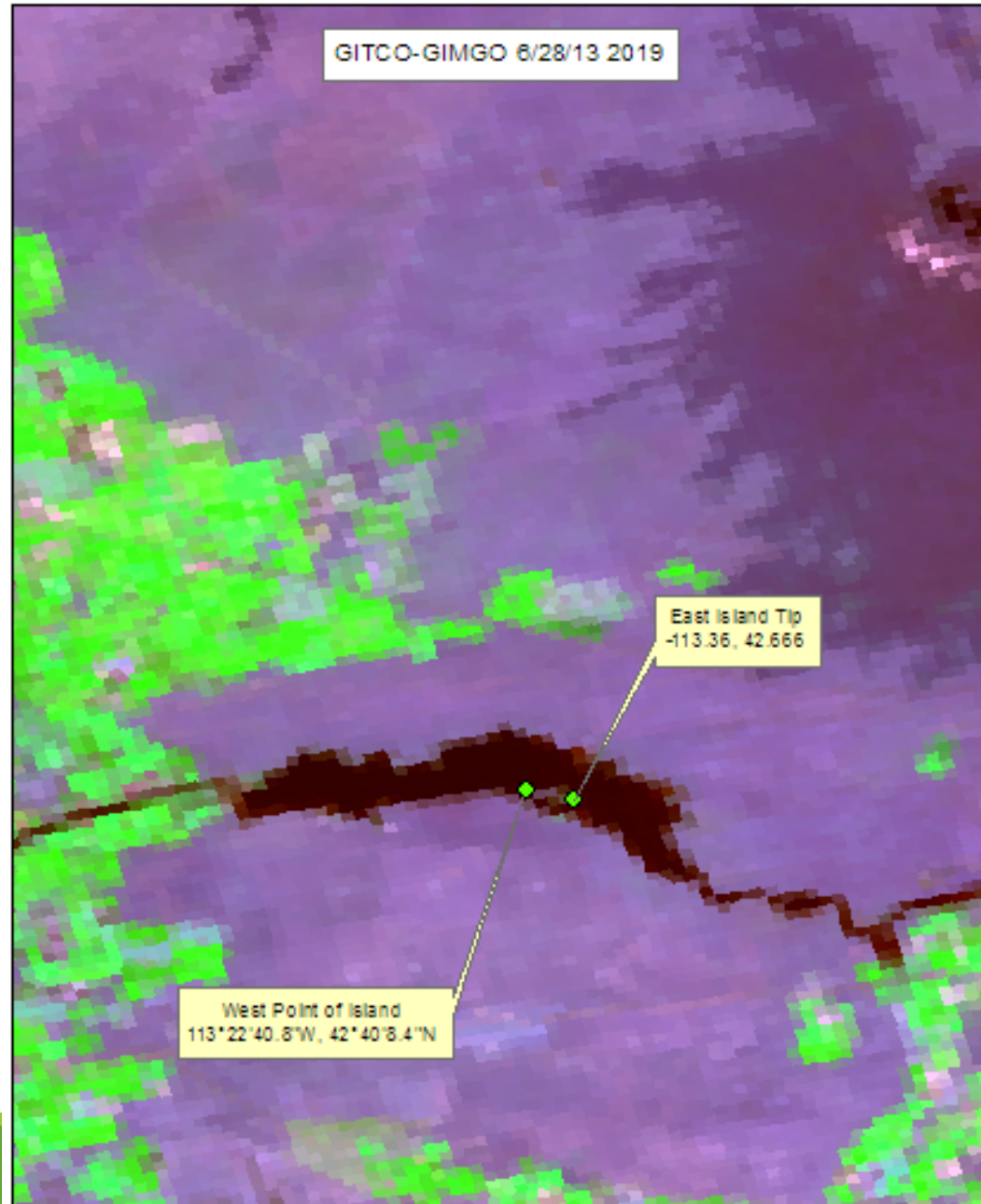


Correct 6/28/13

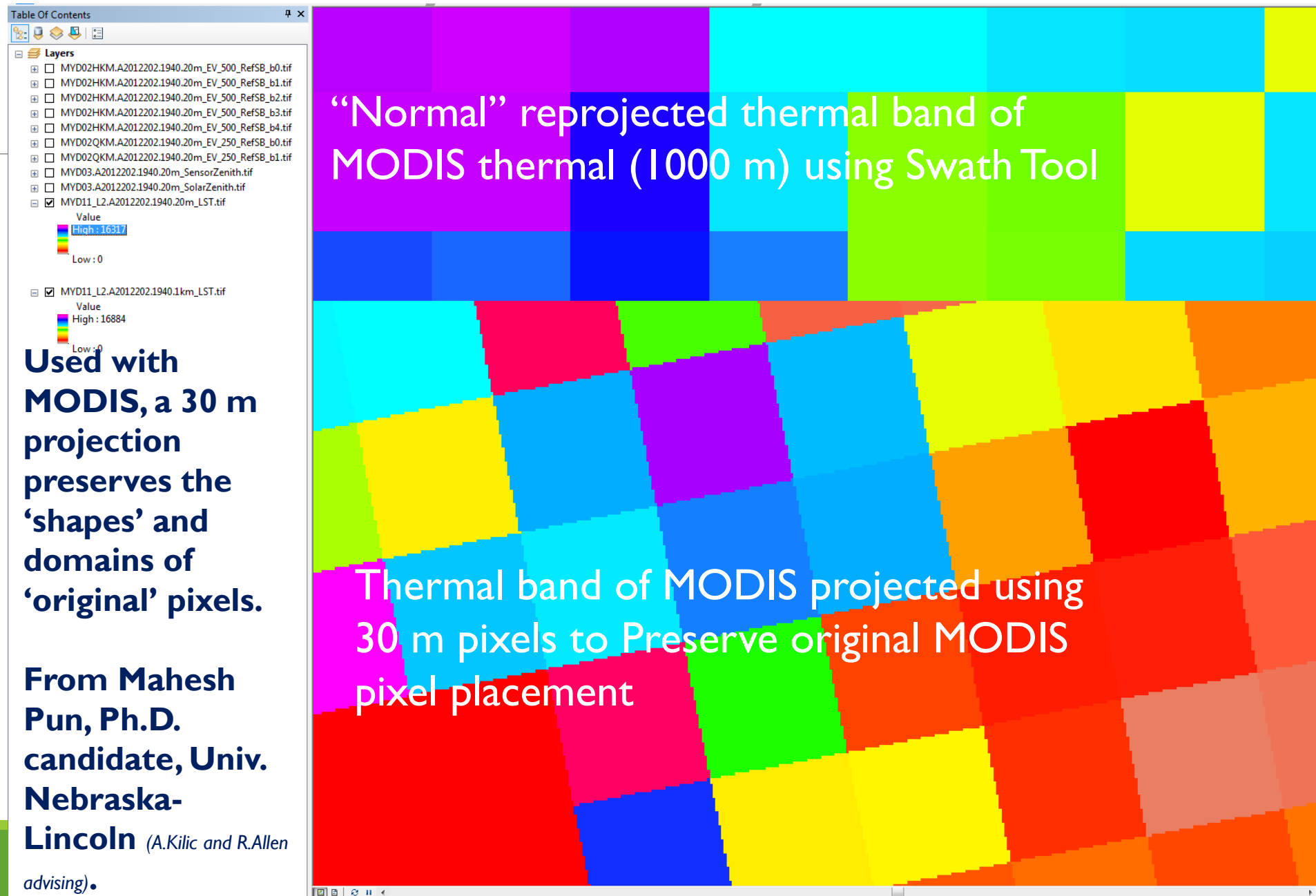


Correct 6/28/13

Reference CDL for 2012



Similar Improvements in MODIS Registration



Summary

Challenge: The ~375 m resolution of VIIRS, coupled with the NW - SW path orientation, makes it difficult to obtain consistent similarity in overlays with typical field layouts that are typically N-S and E-W.

However, VIIRS can be useful to fill in extended Landsat gaps and it is essential to preserve the 'original' VIIRS cell layout as much as possible, via 30 m registration on original ('raw') data layers.

A similar method has been developed at UNL by Mahesh Pun, Kilic and Allen for MODIS products using the NASA SWATH tool.

Idaho Homebrew Procedure Products

Besides performing the resampling at 30 m, the procedure creates a 19 layer image for use with the METRIC model(s) in physical units, rather than digital numbers.

Band 1 -- VIIRS-I1-SDR_All/Radiance [$\text{W}/(\text{m}^2 * \text{sr} * \mu\text{m})$]
Band 2 -- VIIRS-I2-SDR_All/Radiance [$\text{W}/(\text{m}^2 * \text{sr} * \mu\text{m})$]
Band 3 -- VIIRS-I3-SDR_All/Radiance [$\text{W}/(\text{m}^2 * \text{sr} * \mu\text{m})$]
Band 4 -- VIIRS-I4-SDR_All/Radiance [$\text{W}/(\text{m}^2 * \text{sr} * \mu\text{m})$]
Band 5 -- VIIRS-I5-SDR_All/Radiance [$\text{W}/(\text{m}^2 * \text{sr} * \mu\text{m})$]
Band 6 -- VIIRS-I1-SDR_All/Reflectance
Band 7 -- VIIRS-I2-SDR_All/Reflectance
Band 8 -- VIIRS-I3-SDR_All/Reflectance
Band 9 -- VIIRS-I5-SDR_All/BrightnessTemperature [K]
Band 10 -- VIIRS-IMG-GEO-.../SatelliteZenithAngle

Band 11 -- VIIRS-IMG-GEO-.../SolarZenithAngle
Band 12 -- VIIRS-IMG-GEO-.../SolarAzimuthAngle
Band 13 -- VIIRS-IMG-GEO-.../Longitude
Band 14 -- VIIRS-IMG-GEO-.../Latitude
Band 15 -- VIIRS HDF Pixel Row
Band 16 -- VIIRS HDF Pixel Column
Band 17 -- Geodesic Distance to VIIRS Pixel
Band 18 -- Resample grid longitude
Band 19 -- Resample grid latitude

Rapid Production of 30 Years of Landsat-based ET via energy balance in the Central Valley of California



Justin Huntington

Associate Research Professor
Desert Research Institute (DRI)

Charles Morton, Andrew Vitale (DRI)

Forrest Melton, Alberto Guzman, Kirk Post (NASA ARC-CREST CSUMB)

Richard Allen (U of Idaho)



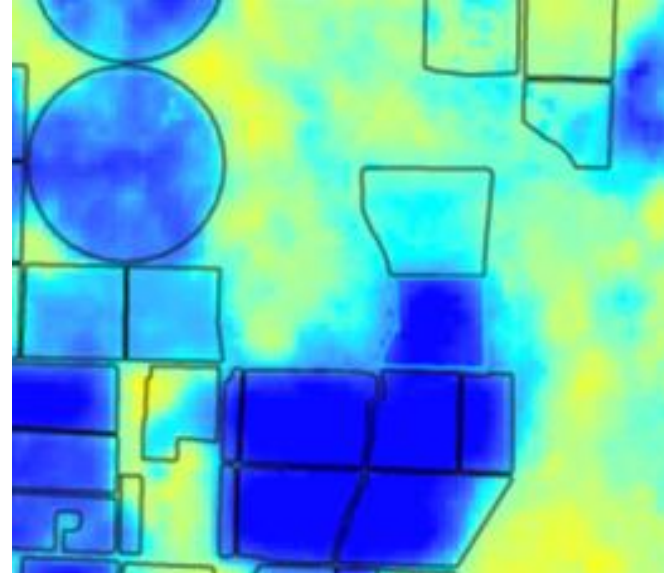
Introduction

Field scale ET is important for understanding agricultural consumptive use

Groundwater consumption in California has been out of control. New laws are requiring both monitoring of depletions and management for sustainable use.

Historical ET maps support predictive studies of surface and groundwater demand

Remote sensing is the most effective and accurate way to estimate actual consumptive use over large areas and long time histories



Goal

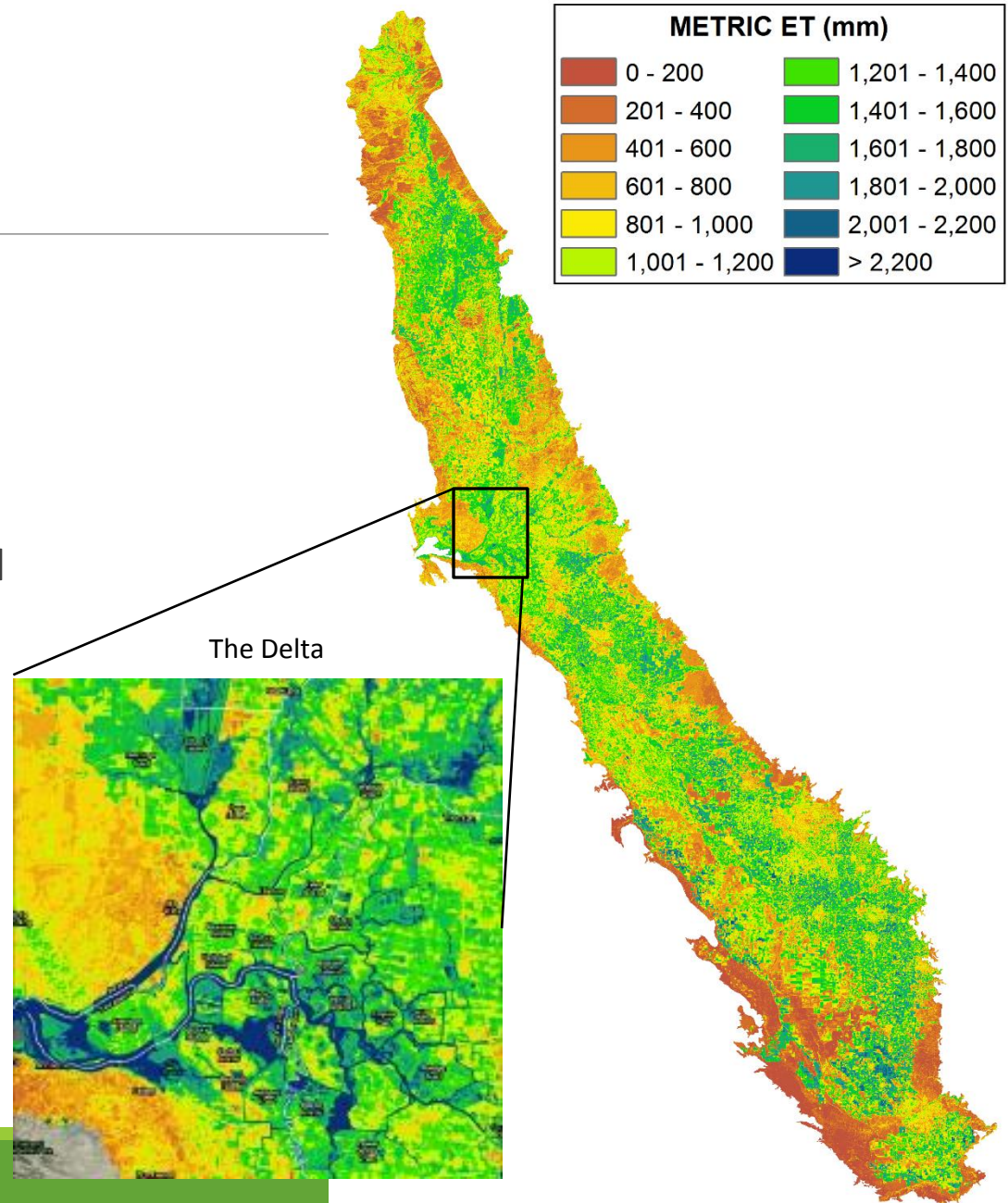
Develop timely maps of monthly & annual ET for a large agricultural area and extended time period

- Central Valley (1985-Pres.)
- Landsat Archive

Develop and implement an automated calibration approach and workflow for METRIC to be run on NASA's Earth Exchange (NEX)

Why Landsat? Field scale resolution - 30~120m

Why energy balance? To account for stress and evaporation not directly considered by optical methods



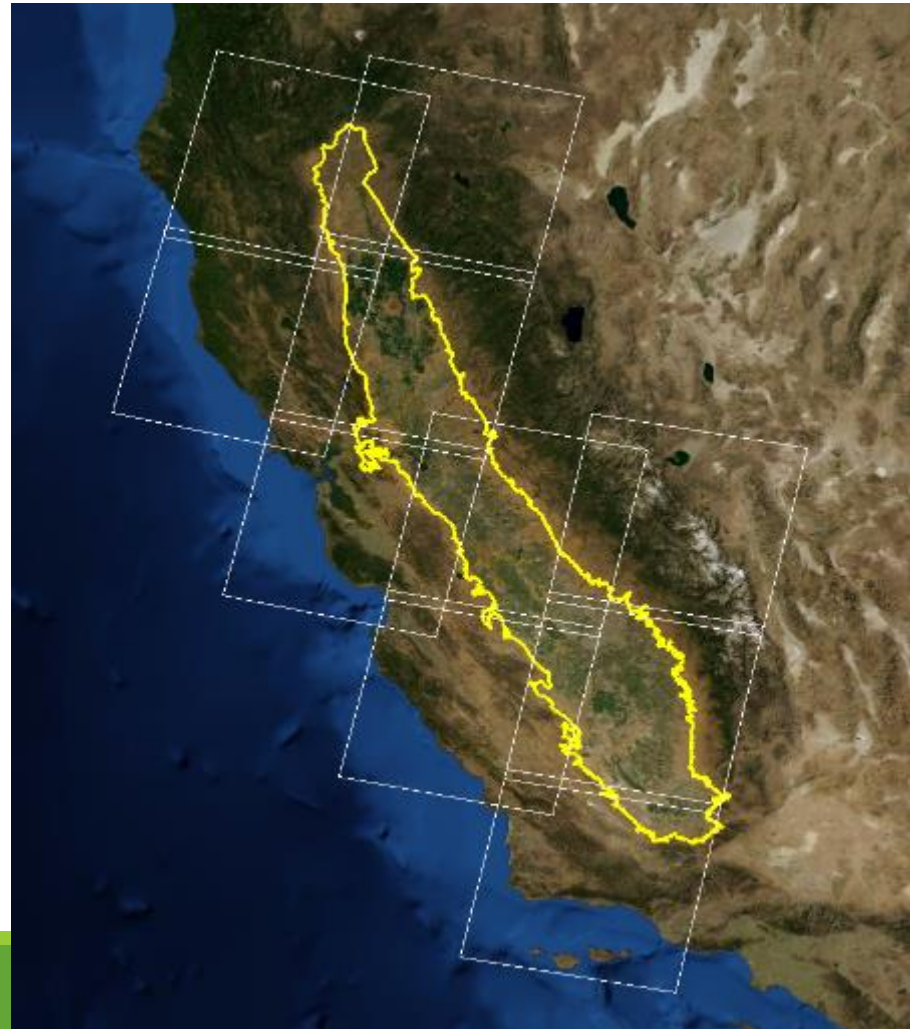
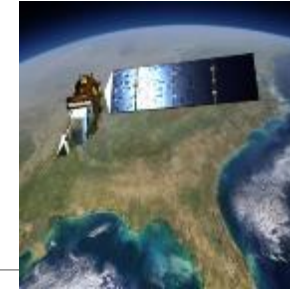
Approach

Use Landsat thermal and shortwave data to estimate ET with automated METRIC energy balance approach

Use gridded weather data to estimate reference ET_r for time integration and for precipitation used in daily soil water balance

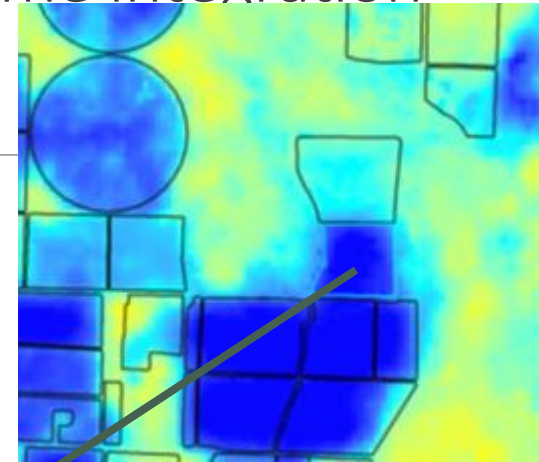
Automation is needed – lots of data and processing..

- ~10 scene areas for Central Valley
- ~22 images / year
- ~30 years of L5,L7,L8 combined
- ~6,000 available images to process..



Monthly & Annual ET – Interpolation and Time Integration

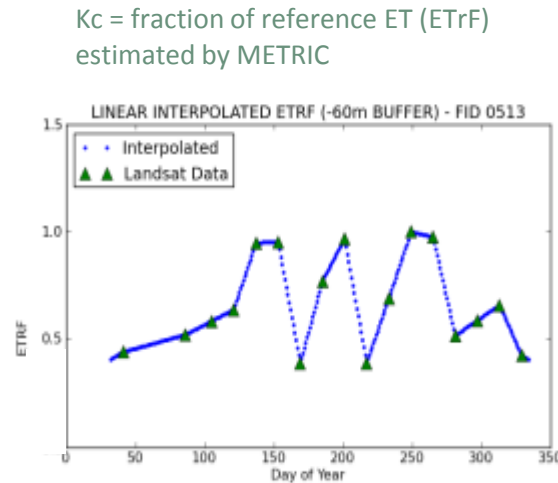
- Water managers need monthly & annual ET, not just snapshots of ET
- We retrieve the fraction of reference ET (ET_{rF}) from Landsat for the satellite overpass time using METRIC
- We time interpolate instantaneous ET_{rF} per pixel in between image dates
- We multiply interpolated instantaneous ET_{rF} by daily gridded ET_r to account for daily weather effects and sum to estimate the monthly and annual ET



Time Series of Reference ET (ET_r)

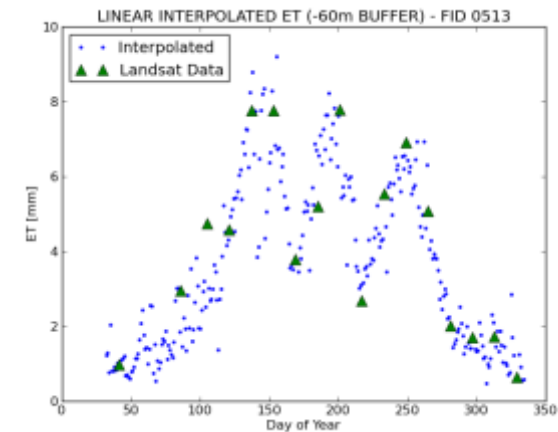


x



=

Total Daily ET (mm)



Automated Approach

MORTON, HUNTINGTON, POHLL, ALLEN, MCGWIRE, AND BASSETT

Automated METRIC approach developed with Python and GDAL

Approach outlined in Allen et al. (2013) and Morton et al. (2013)

Originally developed in Idaho and Nevada

Applied in the Central Valley for 6000 Landsat scenes

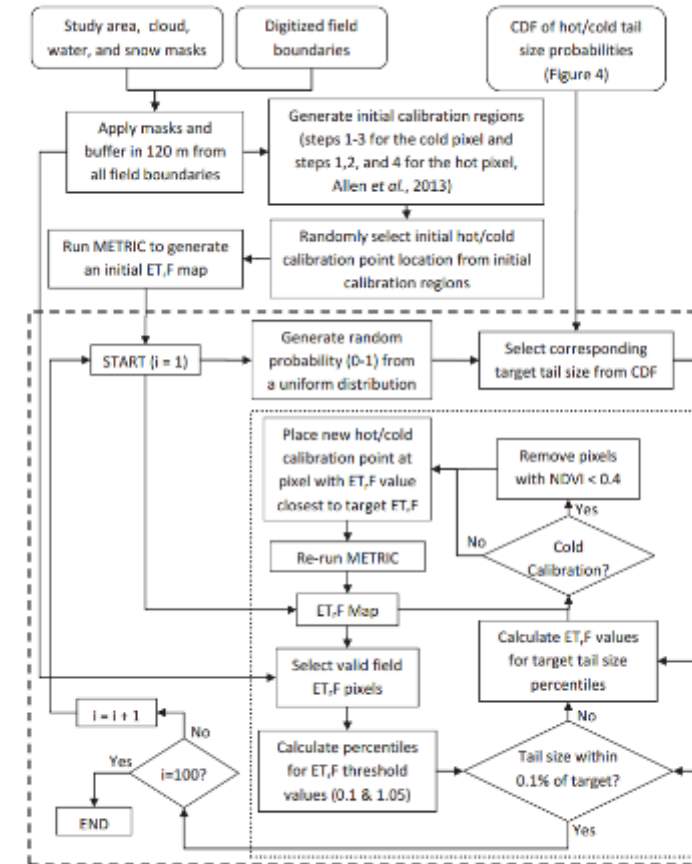


FIGURE 5. Schematic of the Automated Calibration Algorithm. The dashed box is the Monte Carlo process that was repeated 100 times for each Landsat scene. The dotted box is the iterative process to find the hot and cold calibration points that generate an ET,F distribution with the target tail sizes.

Allen, R.G., et al. (2013). Automated Calibration of the METRIC-Landsat Evapotranspiration Process. Journal of the American Water Resources Association (JAWRA) 49(3): 563-576. DOI: 10.1111/jawr.12056

Morton, C.G., et al. (2013). Assessing Calibration Uncertainty and Automation for Estimating Evapotranspiration from Agricultural Areas Using METRIC. Journal of the American Water Resources Association (JAWRA) 49(3): 549-562. DOI: 10.1111/jawr.12054

Upscaling Approach – NASA Earth Exchange



Need to provide ET maps in a timely and costly manner for the entire Landsat archive (1985-pres)

- Lots of path rows and images

Migrated Automated METRIC to NASA's Earth Exchange (NEX) Super Computer

Landsat 5,7,8

FMASK – cloud mask algorithm

ATM Correction – Tasumi et al.(2008)

NLDAS – hourly vapor pressure for ATM correction and ETr

Spatial CIMIS – daily ETr for time integration

SSURGO soils data – soil water balance model

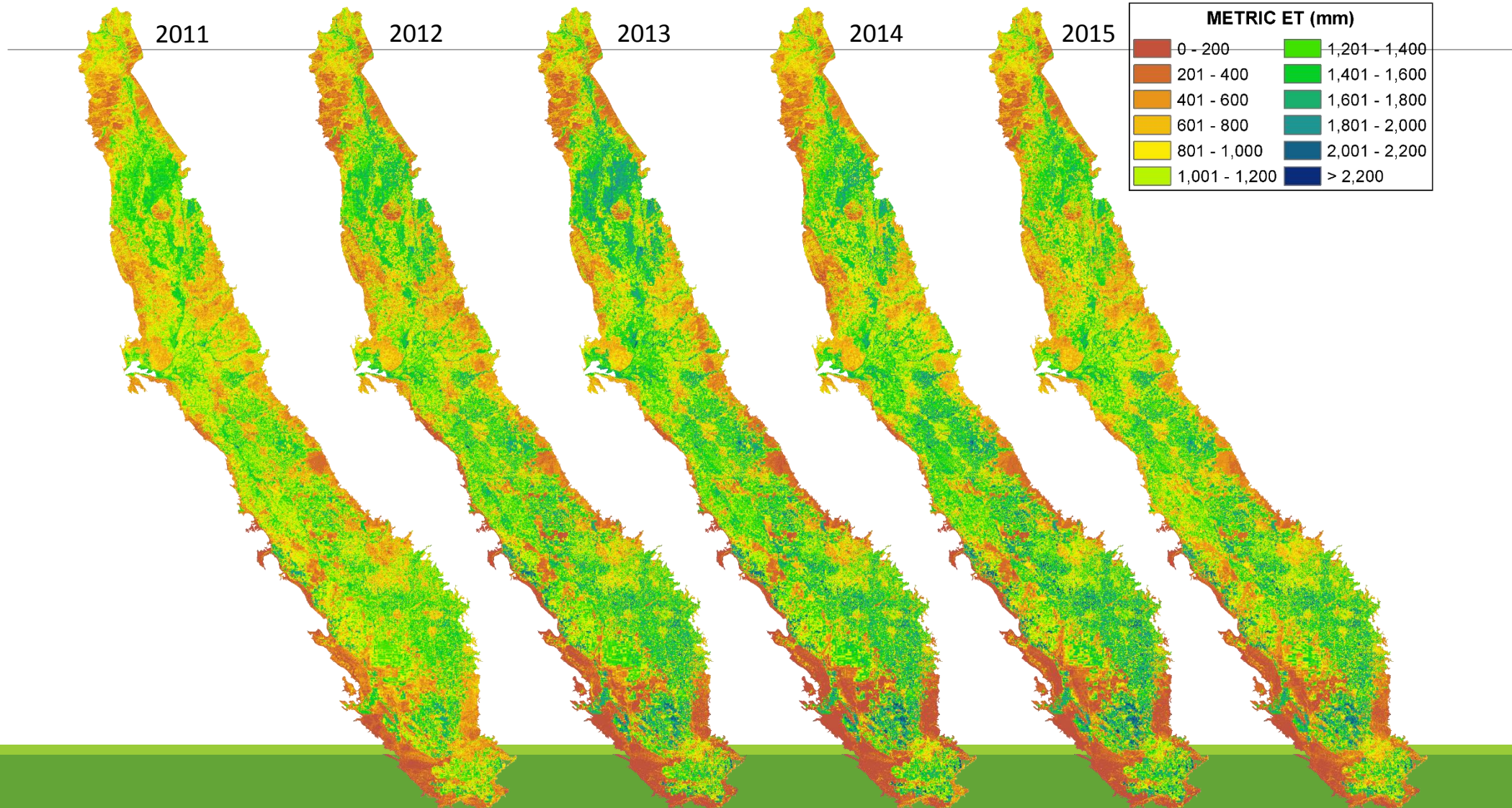
Crop boundaries to limit automated calibration

We run METRIC with Monte Carlo type uncertainty analysis (i.e. ~100 different runs per scene to make 100 different annual totals)

Example Results – ET for the last 5 years

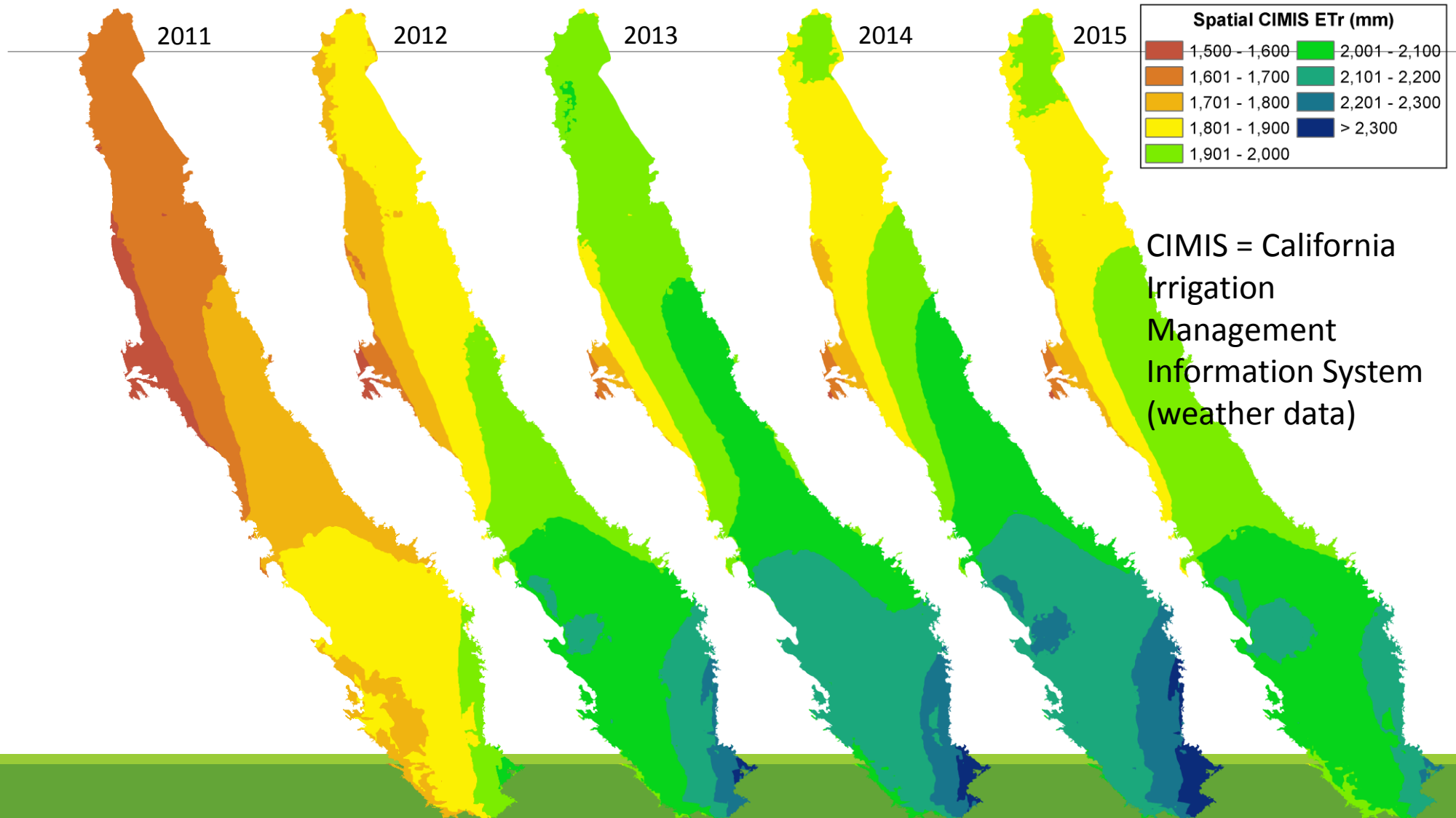
Lower ET during drought in areas that were water limited

Higher ET in areas that were well-watered, especially in 2012 and 2013



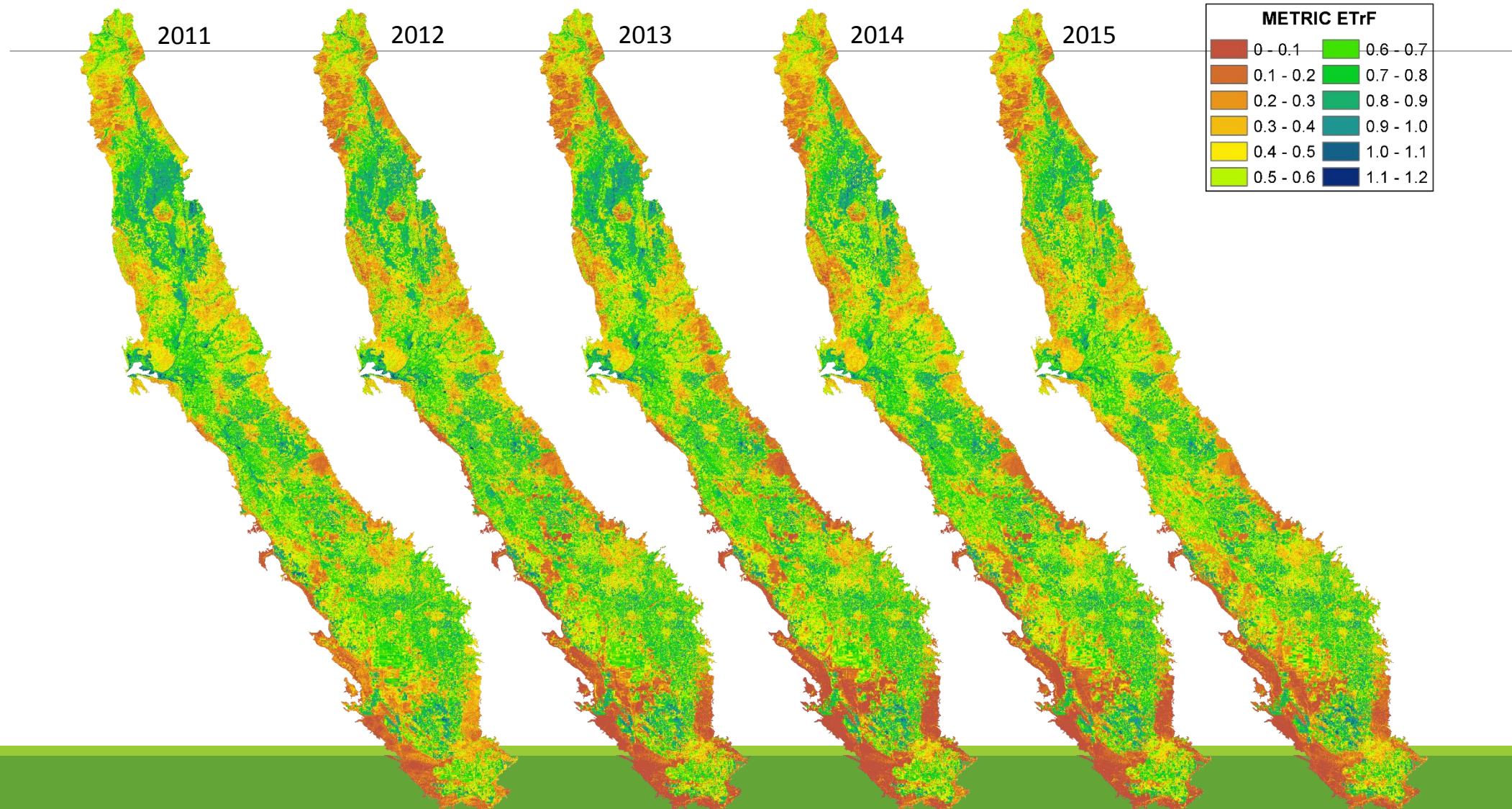
Spatial CIMIS Reference ET (ET_r)

- Reference ET exceptionally high in 2013 - 2015 (complementary theory: decreased PPT = increased ET_r)
- Where water is available, actual ET increases with increased ET_r



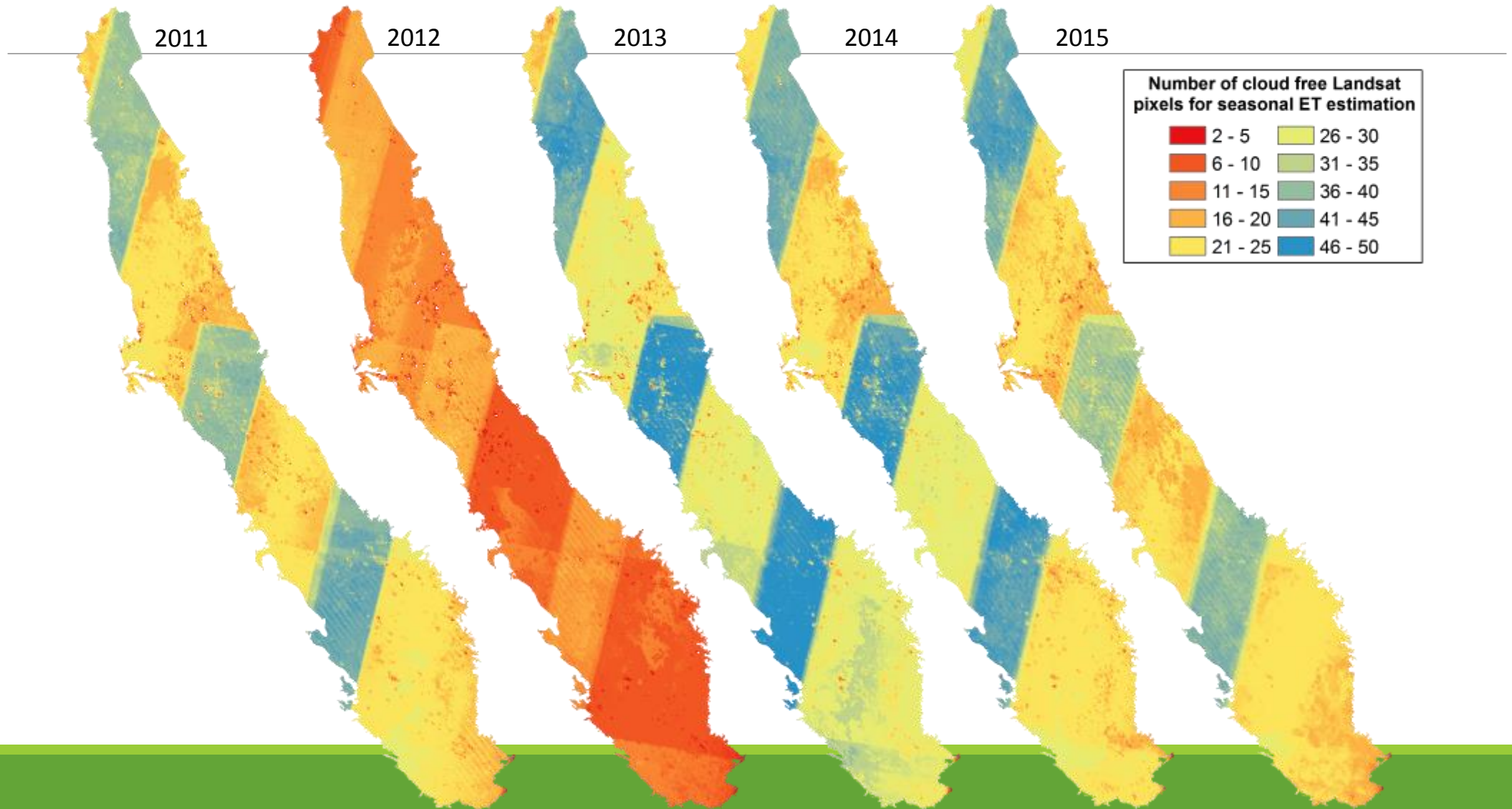
Fraction of Reference ET (ETrF)

- Fraction of Reference ET (ET/ETrF) suppressed in 2015 due to water shortages
- Multiple factors to consider when evaluating ET (ETr and ETrF)



Per pixel Landsat scene counts by year

- Scene counts for estimating annual ET vary greatly - path overlaps and use of Landsat 5, 7, and 8. Only Landsat 7 available in 2012. Important to show scene counts for estimating seasonal and annual ET!

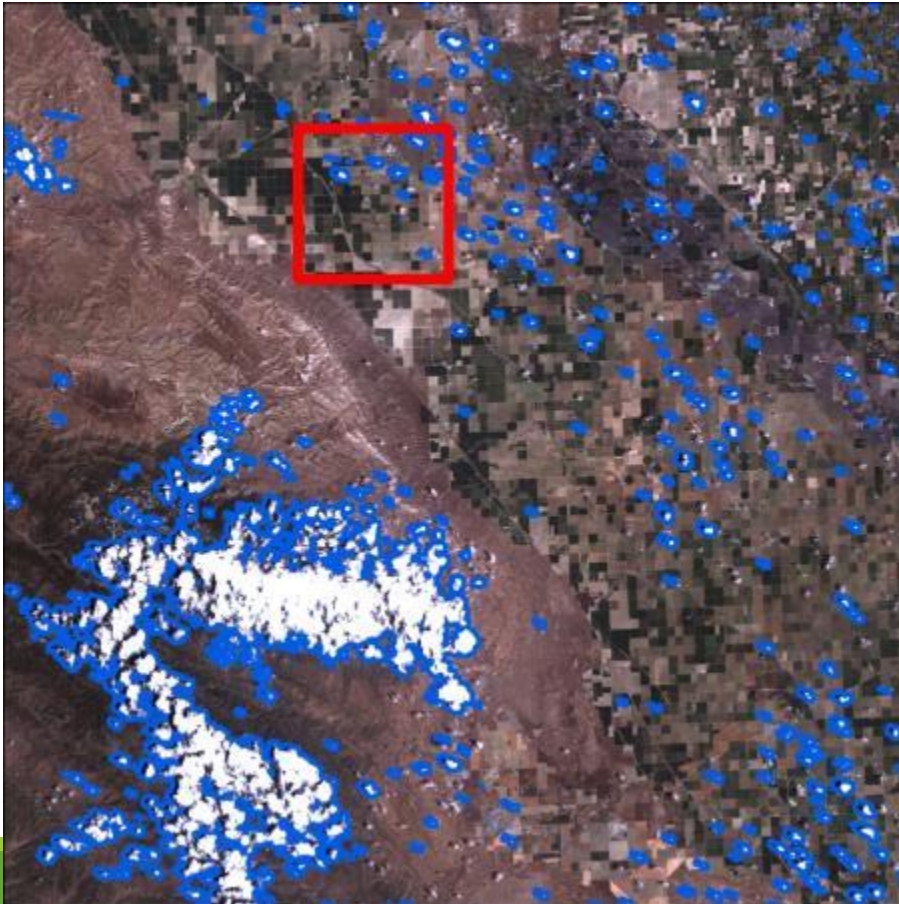


Challenges - Cloud Masking

FMASK sees majority of clouds and shadows, but some slip through

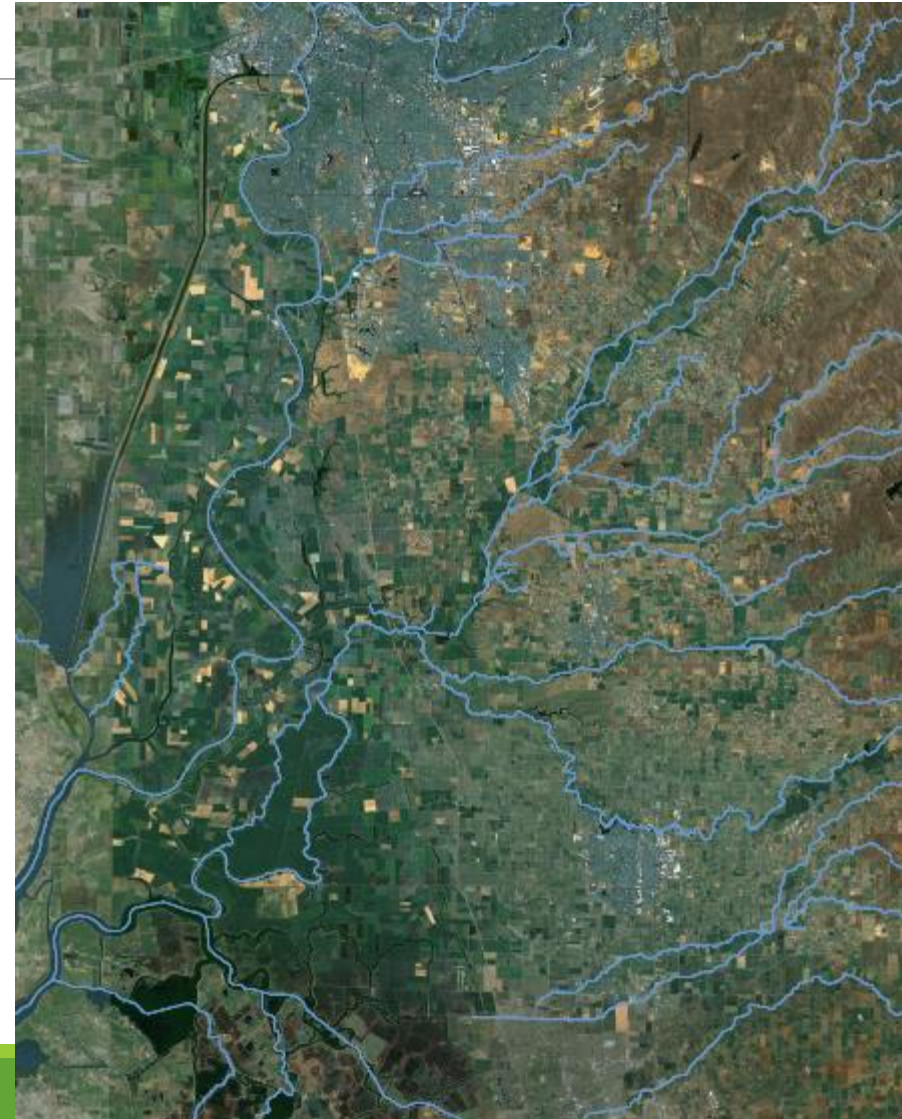
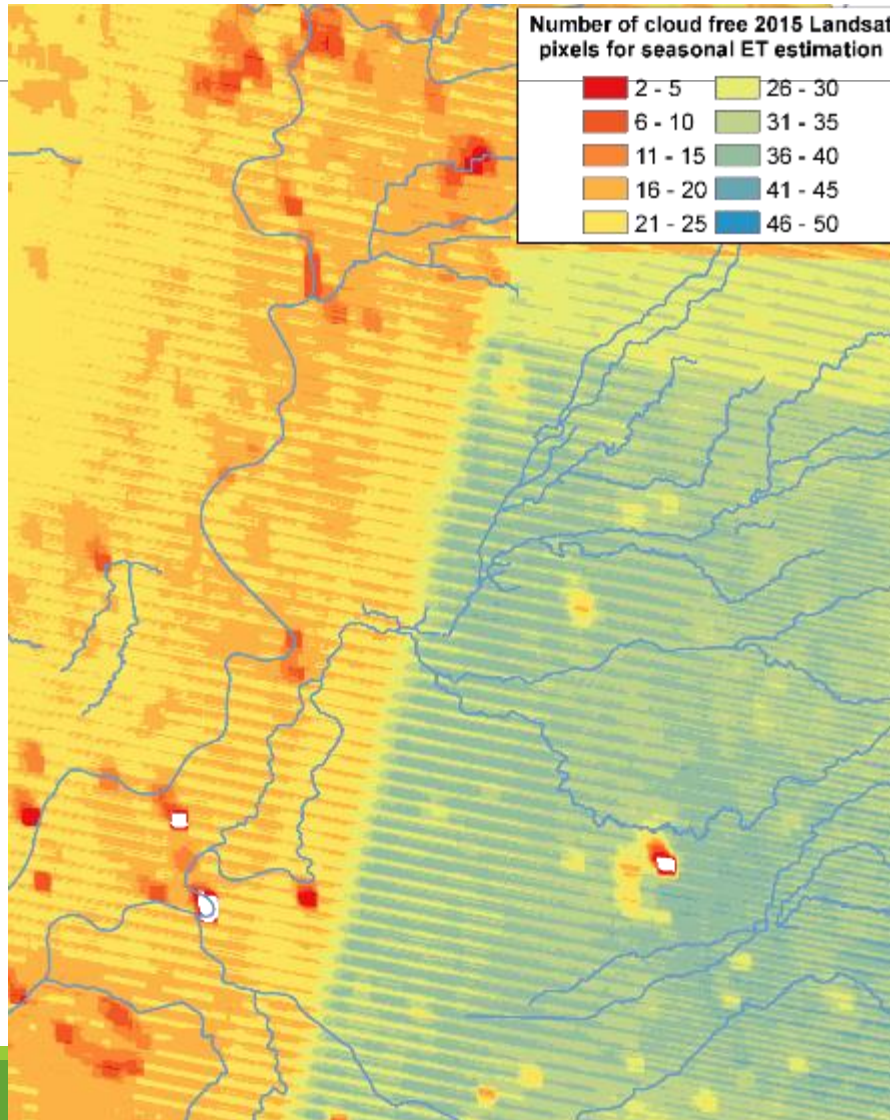
We combine different masks, buffering, and manual masking

We plan to create a cloud based – manual cloud masking app and public database



Challenges - Cloud Masking

FMASK persistence near open water and developed areas

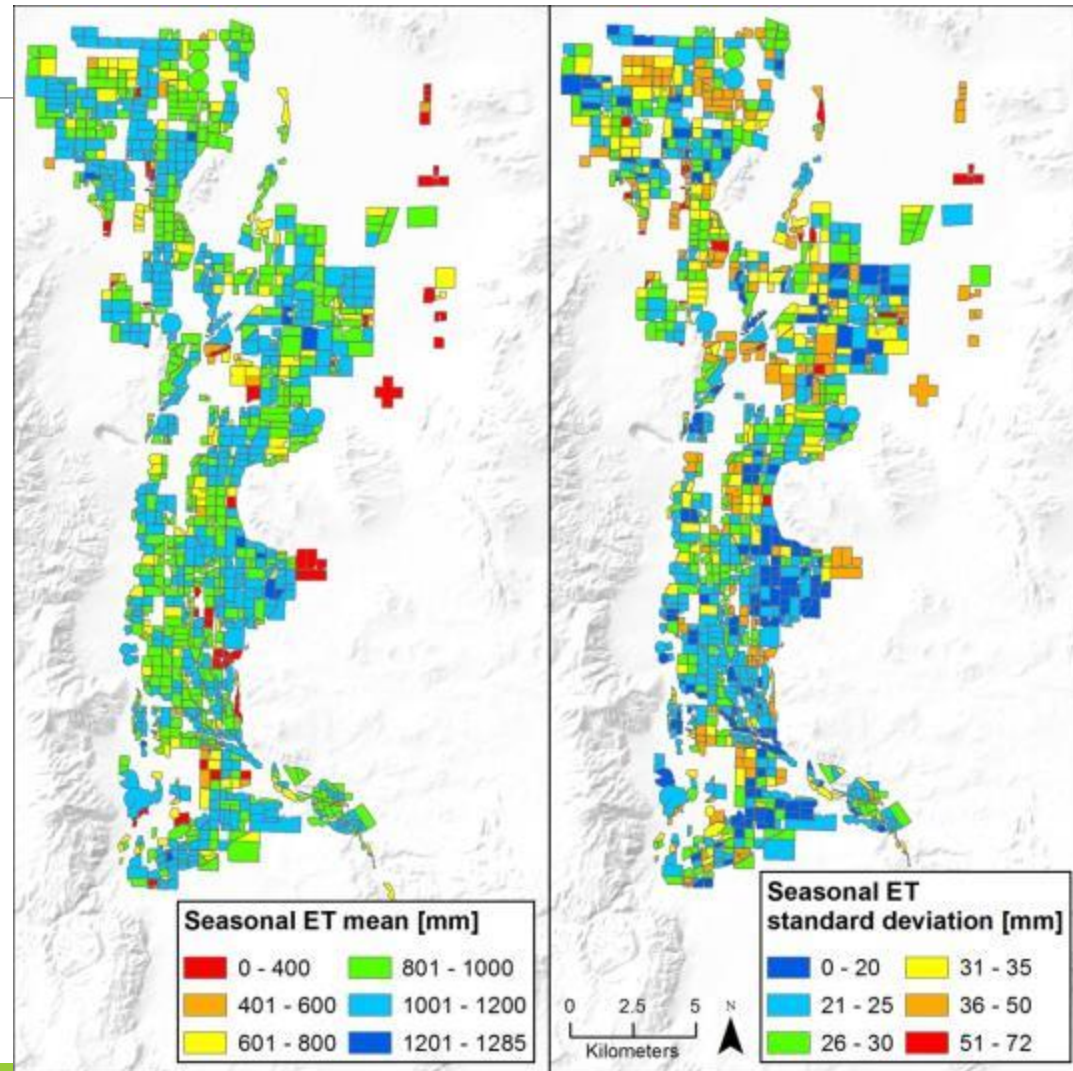


Future Directions for Operational & Automated ET

Adding additional specific energy balance component processes to workflow to overcome limitations (nadir albedo in tall crops, aerodynamic roughness of trees and vines)

Monte Carlo calibration of METRIC to assess uncertainty in ET estimates

Better quantify uncertainties




Summary

We developed and implemented an automated calibration approach and workflow for METRIC to be run on NASA's Earth Exchange (NEX)

The approach allows for timely field scale historical ET estimates for the entire Landsat archive

Once validated, an energy balance ET collection for the Central Valley will be an extremely useful for water use and drought impact reporting, and predictive analyses of annual surface and groundwater demands based on annual supply

The extended Landsat thermal archive (> 30 years) is monumentally valuable for documenting historical and current water consumption at the field scale

A solid green horizontal bar at the bottom of the slide.

Landsat 8, Launched Feb 11, 2013



Many thanks to:

Collaborators

USGS

NASA

Landsat Science Team

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CA Department of Water Resources

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